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Report of Entomological Work in Australia, 1919-1920.

By Frederick Muir.

Leafhopper.

I returned to Honolulu on June 21st, after an absence of thirteen months. When I left last year I considered that three to four months would be ample time to accomplish the object of my journey, viz.: to procure a large colony of *Drypta*.

In my letters from Australia at various times I have mentioned the difficulties that have beset me in my work during the last thirteen months, but I would like to recall them here, as it is necessary for the correct understanding of the time occupied in the work and the results arrived at. In a normal season, without abnormal hindrances, four months should have been ample time to proceed to Australia, collect a good colony of *Drypta* and return. As it was, thirteen months have been spent and the original intention has not been achieved.

Upon my arrival at Auckland in May of last year I first encountered difficulties, as the shipping strike in Australia held the S.S. Niagara in New Zealand for two weeks. This delay was fatal to the *Scolia manilae* I was taking to Queensland, as the cold at Auckland killed them all off. But the Queensland authorities appreciated the effort we made and did all they could to assist me during my stay.

Upon arriving in Sydney I found all the coastal shipping tied up on account of strikes. Had it not been for this I should have immediately joined Dr. Williams and he would have succeeded in getting a large colony of *Drypta* away.

Expecting the strike to be settled each day, I did not proceed overland, as the journey is one to be avoided if possible. I therefore decided to work the southern sugar cane areas, where Messrs. Perkins and Koebele found so favorable conditions in 1904–05.

The 1918-19 season had been exceedingly dry and I found the Bundaberg district, where Perkins and Koebele did most of their work, in an exceedingly bad condition. The sugar crop of the district was only one-third the average and some of the mills in the district did not crush at all; vegetation of all sorts was affected and the grass mostly dried up. Insect life was at a low ebb and one could not believe that it was the same district that Messrs. Perkins and Koebele had collected so much material in.

When the shipping strike was settled I got up north and found the condition very similar. Rains had failed and even in such places as Innesfall, the wettest place in Australia, they were carting their drinking water from some distance. Insect life of all descriptions was scarce and *Drypta* exceedingly so. There was therefore nothing to do but wait for the rains to commence in December and January. In the Macknade district they had one good rain at the end of January, but after that the drought set in again, and it did not break until April 20th. From then until I left, on May 10th, we had only one day in which the sun shone for more than two hours; between April 20th and 25th twenty-five inches of rain fell and up to the 10th of May thirty-seven inches fell. The river was in flood sixteen feet above the bridge, and the creeks were all overflowing and most of the fields with a foot of water. It was only owing to the assistance of the Colonial Sugar Refining Company that I managed to get out of the district to the rail head and get a train for Townsville.

A second shipping strike had hindered my movements, compelling me to go west some three hundred miles and take a motor trip 120 miles from rail head to rail head. The heat out west was excessive, being 120° at Winton the day I arrived, and 110° at Longreach. The drought has played fearful havoc with the western part of Queensland and New South Wales; hundreds of thousands of sheep have died. Along forty miles of road, from one sheep station to the rail, there were sixty dead horses. The dead sheep were not counted.

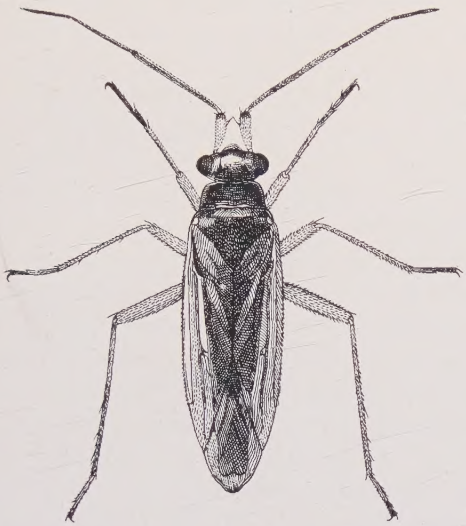
Under such abnormal conditions insect life was exceedingly scarce. In fields where Dr. Williams could collect 100 to 150 Dryptas per day, I could not get fifty in three months. If, after the heavy rains from the 20th to the 25th of April, it had cleared up and been sunny and warm, I believe Dryptas would have appeared in numbers enough to have enabled me to have collected a decent colony, but the continued bad weather and the flooded conditions of the country made this impossible.

The trip altogether was the most unsatisfactory one I have undertaken and I did not accomplish what I set out to do, namely, to get a colony of *Drypta*.

But although I did not do what I had set out to do, yet the time was not wasted as I was enabled to study *Perkinsiella* under various conditions and draw certain definite conclusions that led to the discovery of an insect that I hope will be of greater value than the *Drypta* and will eventually enable us to cope with our leafhopper problem successfully. This insect is a small Heteropterous bug named *Cyrtorhinus mundulus*.

In North Queensland the sugar cane districts are normally wet, especially from January to May, when cyclones often strike the coast and cyclonic storms are common. My last three weeks at Halifax demonstrated what can happen in this line. In spite of this fact *Perkinsiella* is fully controlled.

For several years I have held that the *chief* cause of our leafhopper outbreaks is climatic conditions, such as heavy rains. Mr. Pemberton, after a study of the subject, has come to the same conclusion. These rains are too severe for the minute egg parasites we depend upon for the control of the leafhopper and so they are wiped out and the leafhopper gets ahead. The conditions I found prevailing in North Queensland were such that either my conclusion as to the cause of our outbreaks was wrong or else there were other factors than the egg-parasites in North Queensland that were responsible for the control of the leafhopper. *Drypta* was so scarce that I had to rule it out of the factors acting during 1919-1920, whatever it may do in normal times.



Cyrtorhinus mundulus (Breddin).

The small number of young in the field in comparison to the number of adults made me suspect that either something was impairing the fertility of the hoppers or destroying the eggs. Upon dissecting adult females I discovered the presence of a yeast-like fungus which was numerous in the body fluids. This fungus passed through the walls of the ovarian tubes and entered the eggs, where they were always found congregated in a round mass at the posterior end of the egg. Upon examining eggs laid in the cane leaves I found that 80% were destroyed, having collapsed and, in most cases, a fungus growing from them. An examination of the eggshell under a moderate power microscope showed no break or damage, and I therefore suspected that the destruction of the eggs was due to the fungus. I had no facility for the proper cultivation of this fungus, but the spores from the fructification of the fungus growing from the eggs developed into yeast-like cells similar to those found in the body fluids and eggs. The yeast-like cells from the body fluid and the eggs grow out into hyphae under certain conditions.

Some of my observations led me to think that the fungus was not the cause of the destruction of the eggs, and that the fungus only developed when some other factor had killed the eggs or embryos. This idea was further strengthened when I heard, in response to a question, that the same, or a similar, fungus existed in *Perkinsiella* in the Hawaiian Islands.

It therefore became necessary to find some other cause to account for the death of 80% of the eggs and, after a great deal of field observation, this I found was due to a small Heteropterous bug named *Cyrtorhinus mundulus*. This insect belongs to the same order as the *Perkinsiella* and has similar mouth parts. But, as far as I could find out, it never sucked sugar cane, but lived entirely on the eggs of leafhoppers, which it pierces with its very slender "beak" and sucks out the contents, leaving the eggshell unbroken, the puncture being so minute that it is unrecognized.

The eggs of *Cyrtorhinus* are laid in small crevices in the cane leaf, often in the egg slit of the Perkinsiella. The eggs are parasitized by a mymarid parasite very similar to *Paranagrus* on *Perkinsiella*, but specifically distinct. The young bug is bright scarlet and very active, hiding at the base of the cane leaf. When it comes upon a batch of *Perkinsiella* eggs it feels it all over with the tip of its proboscis (labium) and then inserts its hair-like mouth organs and feeds. The adult is very active and not easily seen as one goes through a cane field, as the movement of the cane leaves two or three yards away cause it to fly off. But by sitting down for half an hour or more in a good situation one can get an estimate of the numbers about and see that they can easily be responsible for the 80% of the eggs destroyed.

I consider that this insect is the chief cause in keeping *Perkinsiella* in check in North Queensland. It is unaffected by storms, as after three weeks of rain and floods the young and adults were as abundant and active as ever. The egg parasite *Paranagrus* is present, but in very small numbers, both at the end of a long dry spell and after the heavy rains, and can play but a minor role in the checking of *Perkinsiella*. *Drypta* was so scarce that it could have played but a small part during the time I was working in the district. Other predators were equally scarce during the same time. I regret not being able to bring back a colony of *Drypta,* as I would like to see it established in our Islands, but I believe *Cyrtorhinus* will be more valuable when once established. Among my collection from Fiji made in 1905–1906 are specimens of this insect; also a closely allied species. By my notes I see that I experimented with it on young hoppers but got negative results. As I was only seeking enemies of the young and adults then, I did not try it out with eggs and so failed to discover its importance.

The question has been raised as to the possibility of *Cyrtorhinus* destroying our *Paranagrus* and so doing more harm than good. To this there are two answers:

(1) If it were to entirely supplant it and was equally effective in destroying the eggs of *Perkinsiella* it would be a gain, as its ability to stand up against the heavy rains in certain districts would prevent some of our worst outbreaks.

(2) There is no reason to believe that it will supplant the *Paranagrus,* as it has not done so in Australia or Fiji. It will attack both parasitized and unparasitized eggs and the joint results will be a distinct benefit. For example,—if they both attack 80% of the eggs then the results of *Paranagrus* alone would be for twenty hoppers and eighty parasites to hatch out of every 100 hopper eggs. If *Cyrtorhinus* was also acting along with *Paranagrus* then the ultimate result would be four hoppers and sixteen *Paranagrus,* the same proportion but a vastly improved condition.

Having failed to get a booking on one of the Oceanic boats, which only take two weeks from Sydney to Honolulu, I could only procure a passage on the S.S. Makura, advertised to sail from Sydney on April 27th. As it took me a week to get from Halifax to Sydney and I had to be in time to arrange passports, etc., I had to start early in the month. Upon arrival in Sydney I found that the date of departure had been postponed till the 3rd of June. This delay, along with the three weeks en route from Sydney, made me despair of getting

anything over alive, but upon examining the cages we found there were twenty-three young and three adults. Since then several of the former have become adults.

We therefore have good reasons to hope that we shall be able to start a colony and eventually increase it so as to be able to turn out fair numbers into the field. This will be a fairly slow process, as they do not increase at a great rate and the supply of food for great numbers will not be easy to maintain.

The question therefore arises if, to avoid considerable delay, it would not be advisable to get a large colony from Fiji, a distance of only eight days.

Now that we know the habits and the best way to handle the insects in cages, this should be a simple matter (barring such hindrances as I encountered in Australia) and should not occupy more than ten to twelve weeks. There is also a second species in Fiji which we could get. The present would be the right time of the year to get it. I would ask to go myself, but my thirteen months wandering in Australia has made me weary of travel for a time. I would therefore suggest that, if it be decided to send for a large colony, either Dr. Williams or Mr. Pemberton should go. It might be useful for the latter to see leafhopper conditions in Fiji, as it would enable him to compare with Hawaiian conditions.

I strongly recommend that some one be sent to Fiji for these insects, as the time saved in establishing them in our Islands fully justifies the outlay. Should anything go wrong with our small colony in captivity, a not impossible contingency, we should then have to proceed to Fiji for a new one.

For the time being I would suggest dropping the *Drypta* until we have established *Cyrtorhinus* and watched its effect upon our leafhopper problem.

Wireworm.

The cable reporting the destruction caused by wireworms reached me after I had left Macknade on my way to Sydney. I could, therefore, not look into the problem myself, even if the entomological conditions caused by the unusual drought had not made such work for this season almost impossible. In conversation with planters and with the Government Entomologists in Brisbane I learnt that in some of the forest land in North Queensland wireworms do considerable damage. It is possible that "white grubs" are the original attraction for this beetle and when they have hatched out or been devoured they then turn their attention to sugar cane. In Fiji wireworms are the worst pest after "borers."

Work on this beetle would take some considerable time on account of the length of the life cycle and the difficulty of getting material to work on. As one of the solitary wasps is the most likely parasite I think the spring would be the best time to work in Australia, providing that the season was favorable.

Antonina on Nut Grass.

Inquiries as to the damage done to nut grass by *Antonina* received very conflicting replies. Nut grass is abundant all through Queensland, especially

in cultivated land. The greater proportion are seedlings and it is through the seeds that cleared fields become restocked. One field at Macknade was of interest as the nut grass was very abundant and when I examined it, in October and November, *Antonina* was present but scarce, and "nuts" not numerous. In April and May the *Antonina* had increased enormously and "nuts" were abundant and covered with the insects. The plant had not flowered, but it was dead and dying all over the field, evidently entirely due to the presence of the insect. *Antonina* was found on two or three species of grasses[1] but did not appear to kill them. Sugar cane was growing in the field in question, a first ratoon, but I could find no specimens of *Antonina* attacking the roots.

I brought back a few specimens and after consulting with the Entomologist of the Board of Agriculture I am trying it out in our quarantine room. If necessary we can procure more from Australia through the post.

The Fern-weevil (Syagrius Fulvitarsis Pasc.).

When in the right districts I searched for this beetle without success. Inquiries of Coleopterists indicate that it is scarce under natural conditions, but abundant in greenhouses at times. No one knew anything of its habits or of any parasite attacking it. One would have to devote one's whole attention to it to do much good.

Acknowledgments.

The Government Entomologist, Mr. H. Tryon, and his assistant, Mr. H. Jarvis, both aided me in every way they could. The Australian Sugar Planters' Association, through their Secretary, Mr. Pritchard, assisted me and gave me introductions to members of their Association wherever I went. But the greatest assistance I received from the Colonial Sugar Refining Company.

The Diffusion of Shredded Cane.

In a communication in the June, 1920, number of The International Sugar Journal, Alfred J. Watts of Pernambuco, Brazil, says in regard to the diffusion in cane "Mr. A. Fries in an article in your February issue quotes Mr. J. N. S. Williams as saying, 'If shredded cane be used for diffusion, this may solve the problem of preparing the material.' I do not know what cutters were used in Hawaii; apparently they were not very satisfactory, but if a 'Fives-Lille' cutter with properly ground knives, changed twice a day only, had been used I do not think he would be worried on that point.

[1] Preserved specimens brought back have been submitted to Mr. E. Ehrhorn, who states that the species found upon grasses is specifically distinct from that found upon "nut grass."

"As every diffusion worker knows, a clear cut slice of beet, or cane, with the minimum of broken pieces and crumbs, which will pack evenly leaving no channels, is the essential factor for good exhaustion without undue dilution, and that the Fives-Lille cutter, with hollow ground blades of the plane iron type and with well-filled hoppers allowing no dancing of the canes, will give. An exhaustion to 0.1 in the exhausted slices is easily obtained in a 16-cell battery and would only be advisable with a pure juice.

"As to the suitability of diffusion chips for fuel, after passing through a 6-roller mill with a moderate pressure and being fed with a screw feeder on the half-cone grate of a 'Godillot' furnace, in my experience they burn perfectly without any auxiliary fuel in the same furnace, except after cleaning. I do not know how much extra fuel has been needed elsewhere, but when I worked the plant in question 20 years ago, slicing over 300 tons per 24 hours and providing fuel for a workshop and locomotives, and steam for a large distillery with rectifier, the daily consumption of poor quality wood-fuel was reduced to nearly 10%. Pressing the work up to 350 tons of course still further reduced the percentage.

"It is so much a question of due attention to economy of heat produced in the first installation of a plant, by covering all hot surfaces, including juice and syrup tanks, saving of all hot water produced including all that from the several cells of the evaporator and much of that from the cooling waters of factory and distillery, and economy in using the steam produced, correct arrangement of flues and furnaces—in all of which details but the last we were very behindhand—that it is difficult to compare one factory with another, especially at a distance; but compared with the majority of factories in the district the diffusion factory had no cause to envy others in the matter of auxiliary fuel, at that time.

"Freedom from serious breakdowns is one great advantage of diffusion, a piece of iron in a bundle of canes being the worst thing to fear; but with a 10 minutes stoppage to replace knives and sufficient spare knives on hand it can be remedied. The chip mills are not pressed sufficiently to render breakdowns likely.

"The amount of 10 tons of firewood to 100 tons of canes worked may seem very high to some of your readers, but there are many deductions and allowances to be made for difficulties that should not be met with in a well-equipped modern factory and under other conditions. The fuel was of poor quality and much had lain for months in wet lowland; the supplies for the distillery, the locomotives and fuel for all the personnel on the place are included. Boiling was all done with direct steam in the pans and three jets of sugar, the first being fine white, were made.

"Taking all things into consideration I do not think that diffusion ever had a really fair trial, and I take it that the scattered nature of the various attempts had something to do with this contretemps."

[R. S. N.]

Examples of the Work of Plantation Improvement.

Industrial Service Bureau, H. S. P. A.

Group of dwellings occupied by semi-skilled employees on an Oahu plantation.

Group at baby nursery on a Maui plantation.

Laborers' concrete quarters, Island of Kauai.

Laborers' quarters on a plantation on Hawaii. Situated along the government road.

General Welfare Work.

By Donald S. Bowman,

Industrial Service Bureau, H. S. P. A.

The plantations in Hawaii have for many years been credited with having better housing and sanitary conditions on their estates than is the case in most countries of the world. Dr. Victor G. Heiser, Director for the East of the International Health Board, which operates under the Rockefeller Foundation, states that "representatives of the Foundation have visited plantations in many parts of the world, including Hawaii, and have found conditions probably more advanced in Hawaii than elsewhere." The plantations are today upholding their reputation for good housing, rapid advances being made to provide still better quarters.

Plantation laborers' community house on a Kauai plantation.

Better Living and Social Conditions:

Throughout the United States a movement for better living and social conditions for the laboring class has developed, resulting in the building of model settlements where trained social workers are employed to look after the general welfare of the workers. We are not behind in this splendid work, which has been carried on in some degree since the first plantation was started.

Industrial Service Organization:

The Hawaiian Sugar Planters' Association realized for some years that the general welfare work should be uniform and that there should be some central organization to act as a clearing house for information, promoting all branches of the work. The Industrial Service Bureau was created at the last annual meeting of the Association. As the title implies, the Bureau is to serve the plantations in any way that will promote and assist in the betterment of general welfare conditions. It is believed that suitable sanitary surroundings, proper modern housing, proper recreation in idle hours, an opportunity for education in conversational English through night schools and club rooms, will and do lead to increasing confidence in one another, and to a better understanding of industrial relations.

Community playground for children. A Kauai plantation.

Absence of Paternalism:

There should be an absence of paternalism in industrial relations on the plantations; labor should in no sense become an object of charity. All activities in social and athletic life should be self-supporting as far as they can be made so.

Welfare Worker:

The providing of community and club houses, amusement centers, etc., are in line with welfare policies that have proven well worth while here and on the mainland. However, we gather from the experience of others and existing conditions that the success of the work depends not so much on the equipment as on the worker. In other words, buildings and equipment are practically worthless to accomplish the desired results without a welfare worker in charge.

Better Housing:

The building of better houses on the unit housing system is acknowledged to be good business and results in contented families. When the strikers returned to work, those who had occupied the modern single-family houses were worried more over their houses than over their jobs, and their first request in many cases was for their former houses.

Sanitation:

Probably the best investment the plantation can make is to insure the workers' good health by providing sanitary and hygienic surroundings. This work should be of a permanent character in each village, and all plans for the disposal of waste water and fecal matter should be carefully worked out and should be submitted to the Bureau before work is started. Full information as to the different and approved methods of waste water and sewerage disposal may be obtained from the Bureau.

Water Supply:

A majority of the plantations hold certificates of approval of their water supply, issued by the Board of Health. To those that do not, and whose supply is subject to contamination, there is just one bit of advice—overhaul your water system and put it in such a condition that a certificate will be issued. This work is most important and should be accomplished ahead of other construction work which has as its object the betterment of welfare conditions.

Feeding:

Cafeterias, restaurants and boarding houses are best provided by or under the supervision of the plantations. There is no argument about the difference in the amount of work a well-nourished man performs as against one who is poorly fed. It is good business to see that the laborers are well fed, and where a sufficient number of men who are not capable of properly feeding themselves are employed, there should be some place where good, wholesome food is served. Should a man wish to live higher than the ordinary eighteen-dollar board, help him to find it. It is far better for him to spend his money on food than for non-essentials.

Food Supply:

In order to insure a supply of fresh food and encourage the raising of chickens, pigs, etc., by the labor, there are many ways in which plantations may help, a few of which are listed:

Assign each family garden space in a suitable location.

Provide a section for the raising of pigs, the best method being to locate the pens alongside of an irrigation ditch, the plantation putting in sanitary concrete floors for the pens, the pig-raisers building the sheds.

Set aside a section for chicken houses and runs.

Provide pure-bred stock to breed from, exchanging boars, etc., with the labor for their scrub stock.

Encourage the raising of vegetables, pigs and chickens by a campaign of education conducted by the Industrial Service or Welfare Worker.

Plantation Store:

The stores as a general rule are not conducted for profit and in most cases undersell their competitors dealing in staple food supplies. This is as it should be. However, the store should cater to the trade and should supply the merchandise demanded. With the present prosperity of the labor many articles of household and personal luxury are being purchased which should be carried by the plantation store.

Dairies:

One of the best investments from a health point of view is the providing of a dairy, in order that the plantation employees of all classes may be provided with pure milk at low cost. Milk is most necessary for the proper development of the child, and is one of the best foods that can be provided for adults. In times of epidemic, such as the recent outbreak of flu, the plantation that could and did furnish milk for the patients obtained the best results.

Meat and Fish:

The use of meat and fish should be encouraged, and the plantation would do well to see that proper supplies at a reasonable cost are to be had.

Amusements:

Amusement is craved by all nationalities, and life is dull indeed where no amusements are provided, especially on the isolated plantations. In providing amusements a careful study should be made and the tastes of the labor considered. They should be provided with what they want and that which will be most appreciated. The carrying on of amusement enterprises should be self-supporting in so far as the expenses of operation are concerned. The motion picture theatres and village club houses have proven most successful and should be installed in all the large settlements. The combination community house and hall for movies, vaudeville and other forms of entertainment is not desirable. It is far better to have the theatre a separate institution, the construction to be permanent in character, with a sloping concrete floor; good seats to be provided. Such a theatre could be used for movies, vaudeville, amateur shows and public meetings of all kinds.

Recreation:

The providing of recreation is a matter to be developed by the Industrial Service Worker on the plantation, and such activities as are demanded and patronized should be in every way encouraged. The best way of arranging a recreation program is by organizing the plantation employees into clubs, etc.,

they conducting the activities under the direction and with the assistance of the Worker. The most popular sports now conducted are baseball, basketball, volleyball, indoor baseball, and track events.

Boy Scouts:

Boy Scout Troops are a great asset to the plantation and go further in teaching Americanism than any other method known. This movement should have the support of everyone interested in the plantation.

Work With Women:

Much good may be accomplished in a practical way among the women and girls by the visiting nurse or woman Welfare Worker, some of the work carried on being the teaching of cooking, household management, care of infants and children, preparation of infant food, sewing, first-aid work, etc.

Education:

No man or woman can be fully competent unless he or she can understand orders and instructions which are given. Educational activities on the plantations should be, in so far as the labor is concerned, along lines that teach conversational English and Americanism. This work can be carried out by the Industrial Service Workers.

The ideas and suggestions presented in this article have all been tried out on plantations; and it is believed that the activities mentioned all tend to improve the morale of the labor and make the plantation a better place on which to live.

A quotation from Roosevelt expresses our sentiments better than any other words we could use: "Unless this country is made a good place for all of us to live in, it won't be a good place for any of us to live in."

An Entomological Inspection of the Kohala District.

By C. E. Pemberton.

The particular object of the trip, apart from general inspection, was to determine the abundance, distribution and injury, if any, of the wireworms which have been so numerous at Honokaa and Paauhau plantations. Soil was carefully examined about the cane fields of all the varieties of cane grown, in freshly planted fields, in young plant and in mature cane, at all elevations from the sea to the extreme mauka fields over the entire district, including the homestead plots above Hawi plantation, as well as Puakea Plantation Company. No evidence was found anywhere of wireworm injury. The wireworm, *Mono-*

crepidius exul, which has been so destructive at Honokaa, is very scarce at present in Kohala. Only one individual was found. This was an adult and indications are that it never has been numerous in Kohala. The blackish white click, or snap beetle, to which this wireworm transforms when fully developed, has never been noted in great numbers at lights about the houses, according to statements by various regular residents in the district. If it had ever been abundant, as at Honokaa, it would very likely be recognized and remembered by the plantation people.

The other species of wireworm, *Simodactylus cinnamomeus,* which has been rather uncommon at Honokaa, is also scarce at Kohala, but more numerous than the first species, *Monocrepidius exul.* The *Simodactylus* is a large, brownish snap beetle. It has been frequently seen at lights in Kohala. Altogether, during two weeks in the district, I found fifteen adults and one larva or wireworm of this species. The larva was found in a cane stool at Union Mill Company, in the ground, but was not feeding upon the cane. There is no indication that this species is injuring the cane in Kohala.

It will be remembered that during April we found grubs of Fuller's Rose Beetle, or Olinda Beetle, *Pantomorus fulleri,* abundantly present in the soil at Honokaa, and it was then considered possible that the great number of wireworms then present was owing to the existence of these grubs. It is known to feed upon other insects and it seemed possible that the wireworms accumulated here, or were attracted here in the adult stage, to avail themselves of the many Olinda Beetle grubs for food. I do not now consider this theory applicable to the situation, in the light of recent observations in Kohala. In all plantations of Kohala, including the homesteaders' fields, particularly above 500 feet elevation, I found the grubs of the Olinda Beetle very numerous—more so than at Honokaa—and adults also very common. Wireworms, however, of both species, though present, were exceedingly scarce.

On June 3, in a mauka field of Striped Tip at Union Mill Company, adult Olinda Beetles averaged about one per every twenty sticks of cane examined. Twelve grubs of the beetle were dug from the soil in ten minutes' time. The grubs of the beetle apparently do no damage to the cane, though they no doubt feed upon the tender cane roots. The exact amount of injury accomplished by them would be interestng to determine. The work is obscure and could be easily overlooked. The grubs actually destroy the roots and kill the plants of several berries and of roses in the States. The adult beetle eats conspicuous notches in the cane leaves, though very little actual damage was noted in Kohala by the adult. One wireworm and ten adults, all of the species *Simodactylus cinnamomeus,* were found in the above-mentioned field of Union Mill Company. The adults were found clustering in the foliage of a shrub near the cane. On the same date, in ten minutes of digging in the soil of homestead plantations above Hawi, fifteen grubs of the Olinda Beetle were found, and in following a tractor which was plowing this field, seventeen Olinda Beetle grubs were picked up in a few minutes' time. No wireworms were seen. On June 5, in an extreme mauka field of Halawa Plantation, ten Olinda Beetle grubs were dug from soil in a Striped Tip field in about five minutes' time. On June

7, in a mauka field of Striped Tip cane of Kohala Sugar Company, one hundred and forty-five Olinda Beetle adults were collected in 110 feet of cane row. The beetles were in the crowns of the stalks, or in the weeds about the stools. Larvae and pupae of this beetle were equally numerous in the soil of this field. From four small weeds (Verbena sp.) about three feet high, in this same field, fifty-one adult Olinda Beetles were collected. The beetle apparently prefers this weed to cane. No particular injury to the cane could be detected in this field where the beetles were so numerous. If there is injury, it will require a detailed and careful study, before proof can be shown. In spite of these large numbers of adult beetles and grubs, no wireworms were found. The Olinda Beetle does not fly and crawls very slowly. Fields that are free now can be expected to remain so for some time and vice versa. Olinda Beetles and their grubs were also common at Niulii and Hawi Plantations and at Kohala Sugar Company.

The *Scolia* parasite of the *Anomala* beetle was found established in Kohala. Two adults and one larva were found at Union Mill Company in a D 1135 plant field at about 500 feet elevation on June 12. The adults were flying over weeds adjacent to the field, one being captured for determination. This individual, which was a male, was sent to Mr. Swezey for final identification. The *Scolia* larva was found feeding on a Japanese beetle grub, about seven inches underground in this same field of cane. The beetle grub was about one-half consumed when the parasitic larva was found. It shows definitely that the *Scolia* is taking naturally to the Japanese beetle in Kohala and some benefit in the future is likely to result. Mr. Swezey writes that colonies of the *Scolia* wasp were sent to Kohala from the Experiment Station in January or February, 1918, and in July, 1919. From these shipments it became established and has no doubt been feeding and developing on the Japanese beetle ever since. It will very probably gradually increase. It forms an insurance for the Kohala plantations in the future, should the *Anomala* beetle ever accidentally reach Kohala from Oahu. There is no reason to expect the parasite to die out, now it is once established, as long as the Japanese beetle remains in the district for it to feed and develop on.

Leafhoppers are everywhere in Kohala. The situation in respect to this is interesting. It is present everywhere and the hopper eggs are well parasitized. The heavy wind and light yearly rainfall serve to keep the cane generally tough and hard. This checks the egg-laying of the hopper, and the parasites reach most of the eggs laid. The absence of rain enables them to attain their maximum degree of efficiency. At Union Mill Company on June 4, in a mauka field of 1921 Striped Tip cane, eighty-four hopper eggs were found in two hours of searching, 85.7% of which were parasitized by *Paranagrus optabilis*. In a makai field of 1922 Striped Tip cane of the same plantation, on the same date, seventy hopper eggs were found after three hours of searching, 88.5% of which were parasitized by *Paranagrus*. From 175 six-inch pieces of cane mid-rib of Yellow Caledonia cane of the 1921 crop, collected at Union Mill Company at 500 feet elevation on June 16, I secured forty-three hoppers, two hundred and thirteen *Paranagrus optabilis* and three *Ootetrastichus formosanus*. This represents a total parasitism of 84.1%. In mauka fields of 1922 Striped Tip cane of

Kohala Sugar Company on June 7, a total of one hundred and fifty-seven hopper eggs were found in one and one-half hours' searching. Of these, 85.9% were parasitized by *Paranagrus* and 0.6% by *Ootetrastichus formosanus*. In two hours' examination of mauka fields of Striped Tip cane, of the 1921 crop, at Niulii Plantation on June 8, a total of two hundred and thirteen hopper eggs were found, of which 90.1% were parasitized by *Paranagrus*. At Halawa Plantation on June 9, in a field of Striped Tip cane, 1921 crop, in the center of the plantation, four hundred and eighty-eight hopper eggs were found after three hours of searching. Of these, 84% were parasitized by *Paranagrus optabilis*, and 10.2% were parasitized by *Ootetrastichus formosanus*. This is a high parasitism, totaling 94.2%. At Hawi Plantation, hoppers were generally scarce, and wherever eggs were examined the parasitism averaged much the same as at the other plantations.

To obtain definite figures on the abundance of adult hoppers over the district, all hoppers found in an average field at Union Mill Company, at 500 feet elevation, were counted, that could be found in two hours of constant searching. A total of eighty-seven were found. Five of these were parasitized by *Dryinid* parasites and one adult *Dryinid* was found of the species *Pseudogonatopus hospes*.

The trash-feeding beetle *Gonocephalum seriatum*, a short, broad, black, slow-moving beetle, present in the soil about the cane, is exceedingly prevalent in the cane fields of Kohala. The larvae of this beetle—a so-called "fake wireworm"—is very common in the soil. It greatly resembles the true wireworms and may be easily confused with them. It forms a definite and conspicuous part of the insect fauna of many cane fields, particularly in Kohala at present. It was so numerous here that an attempt was made to record the extent to which it occurs in the fields. A total of five hundred and twelve larvae of this beetle were collected in a day's time on July 11, at Union Mill Company, in a field of D 1135 plant cane, of the 1922 crop, in a small area amounting to less than one-quarter of an acre. These larvae have been saved for further investigation. The food habits of a soil-inhabiting beetle so common in the cane fields, need further study. It probably feeds only on decaying cane and weed roots and other vegetable matter in a decomposed condition. An attempt will be made later, when opportunity affords, to secure definite data on its food habits. There is a possibility that it may take living cane roots to some extent. It feeds readily on raw potato in confinement. It is checked somewhat on Oahu by a parasite. I saw none of this parasite in Kohala.

Pythium in Relation to Lahaina Disease and Pineapple Wilt.

By C. W. Carpenter.

The so-called Lahaina disease or deterioration of the Lahaina variety of cane in Hawaii has been of general concern to cane planters since about 1909, when serious damage became evident at Ewa Plantation. Since then the disease has manifested itself more or less seriously on Maui and Kauai and throughout the Puuloa and Pearl Harbor sections of Oahu; and more recently on the mauka virgin lands of Oahu Plantation, where the variety H 146 also failed signally in certain areas. There is little doubt, however, that the same disease was responsible for the much earlier failure of the Lahaina variety on the Island of Hawaii.

Similarly we find in the literature references to the deterioration of Bourbon (Lahaina) and Cheribon cane, etc., in other countries, including Java, Mauritius and the West Indies, the descriptions and observations made strongly indicating that the same conditions obtain almost wherever sugar cane is grown. The pineapple "wilt" disease, now so prevalent locally, offers a parallel case in its history.

While no attempt will be made here to review the pertinent literature completely, it is not out of place to cite the experience of other countries with these diseases, and to bring together certain facts which illustrate their conflicting nature. Some writers have held the view that cane varieties are not stable and that they run out after a varying period. It is not denied that there is considerable evidence in support of this view. It is not proposed to take up the question of varietal deterioration[1] extensively, but only as such deterioration appears to bear a relation to our Lahaina deterioration.

In this paper the writer proposes to cite some facts as to the occurrence of this type of disease, facts relating to the character and symptoms of the disease, together with some theories as to the cause which have been advanced. Some experimental evidence in support of the *Pythium* theory is presented, together with plates illustrating the work.

No attempt is made to consider other cane root rots, such as the one attributed to *Marasmius sacchari*, etc., though perchance some confusion exists in the literature and will find its way into these remarks. Root rot is a general term applied to root troubles in general as well as to certain diseases of the roots where no cause can be demonstrated, and thus the above-ground symptoms of the plant may result from a variety of causes. In this paper the term root rot is used in a restricted sense and refers specifically to the type of disease represented by "Lahaina disease" and pineapple "wilt." These diseases are removed *pro tem.* from the category of "physiological" root rots and an at-

[1] Cf. Planters' Record IX, p. 462 et seq., 1913.

tempt is made to demonstrate that the determining cause is a specific fungus of the *Pythium* type.

PART I—HISTORICAL.

Regarding the so-called deterioration of varieties of sugar cane, notably the Bourbon, apparently the same as our popular Lahaina variety, there exists a considerable literature scattered through tropical agricultural journals, etc., only a few articles of which the writer has been able to consult. So far as these articles refer to the deterioration of the Bourbon cane and similar cases, there is a marked similarity to our experience with the Lahaina cane in Hawaii.

Similarly in the literature we find references to the disease called pineapple "wilt." Whether the disease or condition is the same as we are experiencing with this crop cannot be definitely stated. No doubt there are several conditions which bring about the "wilt" symptoms, such as impoverishment, dry weather, and nematodes, in addition to the obscure malady we are investigating in Hawaii.

A few extracts are quoted below from the literature which support the assumption that we are not dealing with a problem peculiar to Hawaii. For the history of these diseases as they occur in Hawaii and for other references to the literature of the subject the reader is referred to the various Bulletins of this Station, and to the articles in the Planters' Record by Cobb, Agee, Lyon, Larsen, Burgess and others.

Sugar Cane.

British West Indies. A few paragraphs on varietal deterioration are quoted from "Sugar Cane Experiments in British Guiana," by Harrison, Stockdale and Ward.[1] (p. 177 *et seq.*):

> "In all over eighty so-called varieties of sugar cane were collected together and these were finally grouped under forty-four names. . . . Despite our efforts nineteen varieties have died out since 1890. . . . They have received similar treatment to plant canes and to ratoons on sugar estates in the Colony. . . . They have been replanted every few years, and thus it may be accepted that they have been under estate treatment. Is this loss of nearly half of the varieties from a collection not of significance? The deterioration of the Bourbon[2] variety of sugar cane has been remarked by every sugar planter in British Guiana and probably in every one of the British West Indian sugar-cane growing colonies, but our experience as above indicated shows that this deterioration is not confined to the Bourbon and to certain seedling varieties.
>
> "The gradual falling off of the Bourbon cane commenced in 1896 and became very appreciable in 1904. . . . The falling off of the Bourbon variety, the old standard sugar cane of the colony . . . was a gradual one. . . . One of the earliest symptoms of 'running out,' 'falling off' or 'degeneration' was a reduction in its capacity for responding to treatment with nitrogenous manure. There was also a change in the color of the foliage and a very apparent falling off in vigor.

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1 West Indian Bulletin, Vol. XIII, pp. 95–218—Harrison, J. B., Stockdale, F. A., and Ward, R. 1913.

2 Lahaina.

"The falling off here illustrated must not be confused with the gradual falling off in yield normal to the cultivation of any variety of sugar cane where the practice of long continued ratooning is followed. . . . Two of us, in 1905, were called into consultation as to the condition of the canes on a certain estate. . . . The Bourbon variety was practically the main variety cultivated. The whole of the Bourbon canes were very seriously diseased, and in fact some fields were so badly affected that the canes were not taken to the mill. The proprietors seriously considered the abandonment of the estate, but by the substitution of seedling varieties, notably D 625, for the Bourbon variety, the estate has been entirely rejuvenated. . . .

"It is almost unnecessary to point out that under favorable conditions of growth the duration of useful life of a sugar cane may be materially lengthened, that a change of soil and environment may brace it to renewed vigor and that whilst a sugar cane may suffer from 'running out' or senility in one locality it may be in full vigor of life and vegetative activity in another.

"An argument which may be adduced in the case of the Bourbon cane against this theory of running out or senility, is that it had been under widespread and long continued cultivation in British Guiana until about 1895 without showing any sign of degeneration. But the records of other sugar-growing countries show that the Bourbon cane has run out in the majority of them and its cultivation has had to be largely curtailed or abandoned. The running out has occurred after very varying lengths of cultivation in different countries. It occurred in Queensland as long ago as 1872, when the variety had been there in cultivation only a comparatively few years. Its effects commenced to be marked in the Northern West Indian Islands early in the nineties of the last century, probably preceded somewhat in Barbadoes, where its cultivation had been the most intensive . . . and followed a little later in St. Vincent."

Further on the statement is made:

"The more noticeable points are that the susceptibility of the Bourbon cane to fungoid attacks is far in excess of that of any other variety now under cultivation in the experimental fields."

Java. Regarding the occurence of root rot of cane or "Wortelrot," in Java, we may quote Lyon:[1]

"'Wortelrot' has been known for many years in Java and has received considerable attention from plant pathologists. In 1903 Kamerling published a book of some 200 pages dealing with various aspects of the subject, but supplying no tangible conclusions.

"In Java the trouble does not appear to any extent in the young cane, but comes on when the plants are about two-thirds grown. In this connection it should be noted, however, that the cane makes its early growth during the rainy season and 'Wortelrot' appears in the dry season.

"While in Java I made a careful study of this trouble and the work which had been done upon it by the Java pathologists. The following paragraph is taken from my notes made at that time:

"Canes are apt to die off early in the dry season; this is especially true of some varieties, i.e., Cheribon. Their root system fails to per-

[1] Lyon, H. L.—Planters' Record XII, No. 5, pp. 297-298, 1915.

form its proper functions; the old roots die and no new ones are produced, and consequently the cane dries up. They look upon this in Java as due to the aging of the cane, or lack of vitality due to old age. Miss Wilbrink says it is not caused by a fungus even in part. When the cane begins to die of 'Wortelrot,' watering will not save it or seem to help it."

Sorauer[1] has the following to say about the root rot of cane:

"Among the numerous diseases of sugar cane, root rot plays an important part. In Java it is considered the worst enemy of sugar-cane culture. Naturally growers have not failed to cite the microroganisms [*Verticillium* (*Hypocrea*) *Sacchari, Cladosporium javanicum* Wakker, *Allantospora radicicola* Wakker, *Pythium*, etc.] colonizing on the diseased roots as its cause. Nevertheless, Kamerling's[2] recent experiments have now confirmed beyond all doubt the supposition that a constitutional disease is concerned here, resulting from compacting the soil. Raciborski, with Suringar,[3] has expressed the theory, earlier proved, that by transplanting sugar cane which had suffered from the root disease known as 'Dongkellanziekte' to other soil, the plants would become healthy. The disease occurs especially in heavy clay soils and manifests itself in Java, when at the beginning of the spring monsoon the plants die with alarming rapidity after they have already shown for some time an abnormal branching of the roots and also deformed root hairs. He investigated the soils in which the disease occurred and found that they did not have sufficient friability and easily became compacted. The permeability of the soil can be increased by supplying humus, since this, as also ferric hydroxid or silicate rich in iron, favors the formation of friable soils. Since the humus is gradually lost by oxidation, care must also be taken to retain the porosity of the soil by a renewed supply of stable manure, rice straw or green fertilizer (compost)."

That a fungus of the *Pythium* type has previously been observed in cane roots is indicated by the following extract from Wakker and Went[4]:

"In the first treatise on sereh disease Treub[5] mentions, besides an Heterodera (nematode) . . . a mold found by him on the roots of sereh diseased cane.

"He classifies this mold as most probably belonging to the genus *Pythium,* with which it really has some resemblance, and the consequence was that in the later literature on sereh disease the presumptive *Pythium* is always mentioned as the probable cause of sereh. Strangely enough, no close investigation was made until 1891, when Tschirch published an article wherein he classifies the above mentioned mold under the endotrophic mycorhiza of Frank. It seems to me that he is right. True enough, Treub states that when pieces of the root containing the fungus are placed in water, certain swimming spores which belong to the *Pythium* type appeared, but about any relation between the two nothing can be found in his treatise. I would suggest that the name

1 Sorauer, P.—Manual of Plant Diseases, Vol. I, pp. 228-9. 1905-1909. Translation by Frances Dorrance. 1915.

2 Kamerling, Z.—Verslag van het Wortelrot Onderzoek, Soerabaia. 1903.

3 *In* "Mededeelingen van het Proefstation vor Suikerriet in West-Java," No. 48. *Cit.* Zeitschr. f. Pflanzenkr., 1901, p. 274, and 1908, p. 88.

5 Treub, M.—Onderzoekingen over Sereh-ziek Suikerriet. Mededeelingen uit s'Lands Plantentuin II. 1885.

4. Wakker, J.H. en. Went. F.A.F.C. — De Ziekten van het suikerriet op Ja[illegible] 18[illegible]

Pythium for our first root mold be dropped and for the time being simply call it Root Fungus No. 1.

"The following are my personal observations regarding this peculiar fungus. When examining the thin roots of the sugar cane we nearly always find strong, winding, thick-walled fungus threads inside the cells. Treub mentions the same about the roots of sereh diseased plants. In certain preparations I saw that they were connected with similar fungus threads which run between particles of the soil. . . . As Treub describes and as roughly sketched by Tschirch, the threads often form close clews in the deeper cells of the cortex. Here they are always thinner than the first mentioned threads and often they are difficult to find on account of the protoplasm of the attacked cells having changed to a crumbling mass of low transparency. The mold threads themselves having died off here and there. . . . Cross walls appear here and there, but always as an exception. Except in the soil and in the cortex cells of the thinner roots, I have never found this fungus.

"At the ends of the threads, both in the soil and in the surface cells, round objects are found, sometimes deformed by the shape of the cells to a more or less cylindrical form. At first sight they look like propagation organs. . . . Sometimes these round bodies have thick walls, wherein different layers can plainly be distinguished. . . .

"While Treub considered this fungus a parasite causing the death of badly infected plants, Tschirch believes, in accordance with the theory of Frank (endotrophic mycorhiza), that the cane is not injured by this fungus, but that by symbiosis it may be useful to the plant. There is no proof, . . . and I believe it better to classify this fungus with the parasites.

"It is quite true that once in a while a strong development was found in dead roots (*Saccharum ciliare*), but there was no proof that the fungus was the cause of death, and cannot very well be furnished as long as *pure cultures of the fungus are not known. So far nobody has succeeded in obtaining these*.[1] I only want to add that no root fungi are found in the roots in sterilized soils."

Besides the deterioration of variety or senility theory, brought out in a previous section, many theories have been more or less thoroughly investigated, especially in Hawaii. Although a theory of a fungus or other parasite as a cause has been advanced before in other countries as well as Hawaii, to the writer's knowledge no experimental proof of parasitism has been obtained. It is not proposed to review the various theories in detail, but merely to cite them and the apparent conclusions reached, if any, to illustrate the elusive nature of the problem, and the attention the disease has received.

Among the theories advanced and rather completely investigated in Hawaii are the following:

1. Attacks of parasitic organisms.
2. Senility, deterioration or running out of variety.
3. Root rot.
4. Soil toxins.
5. Lack of available plant food.
6. Bacteriological relations.
7. Black alkali.

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[1] Italics, the present writer's.

Cobb[1] took up the study of root disease of cane in Hawaii, and considered such fungi as *Ithyphallus, Clathrus, Dictyophora,* and *Marasmius. Marasmius sacchari* is generally accepted as a cause of a certain type of root rot. As to the causal relation of species of *Ithyphallus, Dictyophora* and *Clathrus* to the disease of cane under investigation, to which fungi much of the damage was attributed by Cobb, no proof was offered.

Amongst a wealth of detail, the abilities of the fungi as parasites were neglected. At the most *Ithyphallus* is claimed by Cobb to be a wound parasite.

Lyon[2] attacked the problem from the first three angles above mentioned: Parasitic organisms, senility, root rot. He summarizes his investigations as follows:

> "Careful microscopic and cultural studies, however, though long continued and oft repeated, failed to reveal any parasitic organism which could possibly be responsible for the disease. The transfer of diseased roots to the soil about the roots of healthy canes failed to transmit the disease. Cuttings from diseased plants produced strong, healthy stools when planted in other soil. Diseased stools recovered when transplanted to other soils. As a result of these studies and experiments we were forced to conclude that the trouble could not be ascribed to parasitic organisms."

As to the senility theory, that Lahaina cane

> "has not lost its ability to grow and produce as large and vigorous cane as ever, if its present requirements of soil, temperature and moisture are satisfied, is amply demonstrated by the following history of a few stools of Lahaina cane:
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> "The stools mentioned were some of the worst that could be found at Waipio. They were dug out and with the soil clinging to the roots were planted at Honolulu (May 21).
>
> "By the end of the summer these stools had produced a perfect stand of as healthy Lahaina cane as could be found anywhere in the Islands.
>
> "The nearly dead, constricted, original sticks resumed growth and became nearly as robust as the sticks from the new shoots. Some of the constricted sticks grew 15 feet after being transplanted.
>
> "This little experiment would seem to effectually eliminate senility and parasitic organisms as plausible explanations for the Lahaina disease. . . . Lahaina disease must therefore be diagnosed as Root Rot. Its correction is a problem in soil sanitation."

In subsequent work, Lyon[3] detected the resting spores of an organism said to belong to the *Chrytridineae,* in the roots of cane and pineapple. Almost simultaneously with the present writer[4] the theory was advanced that both Lahaina disease and pineapple "wilt" were possibly caused by the same organism. Subsequent work[5] on the *Pythium* theory by the present writer in-

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1 Cobb, N. A.—Pathological Bulletins 5 and 6. H. S. P. A. Experiment Station.

2 Lyon, H. L.—Planters' Record, Vol. XII, pp. 299-304. 1915.

3 Lyon, H. L.—A preliminary report on the root rot organism. Planters' Record, Vol. XXI, pp. 2–8. 1919.

4 Hawaii Agricultural Experiment Station. Press Bul. No. 54. 1919.

5 L. c.

dicated that the resting spores studied by Lyon were identical with the resting spores of the *Pythium* type fungus.

Peck and Agee[1] investigated the Lahaina disease on the theory of soil toxins and tried a number of soil treatments, including different forms of lime, carbon black, pyrogallic acid, green manuring, fallowing, etc. The character of growth of Lahaina cane in affected soil, virgin soil, sterilized affected soil, sterilized virgin soil, and mixtures of 80% virgin soil and 20% affected soil, was observed. Sterilization of affected soil resulted in an increased growth. Leachings from affected soil failed to induce disease in plants watered therewith. The most encouraging results from Peck and Agee's experiments were the gains of plots where green manuring was practiced over fallowed plots.

Burgess[2] found some correlation between the occurrence of Lahaina disease and the presence of black alkali in the soils. In his opinion black alkali is not the only cause of Lahaina disease, but is doubtless a contributing factor.

As to available plant food, Burgess concludes: "Lahaina disease cannot be attributed to lack of available plant food. In many cases more is present under the poor cane than under the good."

Some work was done by Burgess along bacteriological lines, with results as indicated by the following quotation:

> "From the bacteriological work which has been done on these soil samples it is very evident . . . that we must turn activities in other directions are we to find the true cause for the deterioration of Lahaina cane on Maui, Oahu and Kauai."

Pineapple.

It should be emphasized again (cf. p. 142) that we have no satisfactory means of determining readily the disease termed "wilt" of pineapples and differentiating the epidemic disease from those other diseases or conditions resulting from poor soils, lack of water, malnutrition, etc. Besides examining the plants one must be familiar with the field from which the plant is removed, and preferably make a field examination before an opinion can be hazarded. Like the term root rot in the broad sense, "wilt" is a collective term, but we are attempting to limit its meaning in this paper to a narrow sense, signifying a spreading and destructive disease, which gives evidence of being parasitic in origin, at least in part.

An article by H. T.[3] in the Queensland Agricultural Journal furnishes a rather comprehensive account of a pineapple disease occurring in Queensland, which suggests the "wilt" of this crop as we know it in Hawaii. This article, while comprehensive as to observations on the disease, is unfortunately very superficial as to facts from experimental evidence, and as to the fungus mentioned as associated with the disease, nothing is furnished in the way of a description from which we can determine what sort he observed. Some signifi-

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1 Agee, H. P.—Planters' Record XII, pp. 374-389. 1915.

2 Burgess, P. S.—Planters' Record XIV, pp. 303–326, 353–370. 1916.

3 H. T. (Tryon ?)—"The Pineapple Disease," by H. T. Queensland Agricultural Journal, Vol. XV, Part 1, pp. 477–485. 1904.

cant statements which may have a bearing on our pineapple problems are quoted below:

"In 1887 the growers of pineapples at Mundah, . . . became greatly concerned on discovering that these plants were failing, and this in spite of all effort to obviate so undesirable a contingency. And they even anticipated that the fine orchards there would be extinguished if this affection continued to spread as rapidly and extensively as it had recently done. These expectations have not been realized; but nevertheless pineapple growers have in some instances ever since then experienced by reason of its occurrence considerable annual loss . . . the malady complained of has not been general in the district, and even those growers who have had to lament its presence are already persuaded that, as has happened in the past and so may transpire in the future, their cultivations will become free of it. All . . . will welcome an exposition of its true nature and of the circumstances which determine its capricious occurrence at particular seasons and in definite and special localities.

". . . it may be remarked that pineapples when affected by this disease in question present the following distinctive features: Their ordinary somewhat darkish-green hue gives place to one in which red and yellow predominate; or, owing to the wilting and twisting of the leaves from their points downwards, a brownish tint pervades the plantations . . . the leaves have lost to a certain extent their usual turgidity; they lack the full rigidity so characteristic a feature in the leaves of the healthy pineapple plant; and if they bear fruit at all, this has already assumed a yellowish hue long prior to the time when under ordinary circumstances it should do so. As usually happens there are far more pronounced symptoms of decadence, for the plant has both commenced to die back and become rotten. The apical leaves and shoots have either already fallen away or may readily be removed *en masse* by the hand for . . . they are already decayed at their bases of attachment. . . . On lifting from the ground a plant presenting these symptoms, it will be found that the roots proper and rootlets are already dead and in an advanced stage of decay, and that no new ones are succeeding them. A longitudinal section through a pineapple plant in which the disease is not far advanced reveals the fact that as regards its external manifestations decay has commenced at the growing apex, proceeding thence downwards into the stem.[1] Further inquiry will render it evident that very early in the history of the disease, and even when these external symptoms are still unmanifested, the roots or rootlets have already perished. . . .

"In the earliest indication of root disturbance encountered both roots and rootlets are normal in appearance, but the microscopic hairs which so thickly clothe them, instead of being obtusely pointed simple cylinders, are terminally widened and twisted. . . . Then, as an illustration of further development, the pineapple plant has its roots and rootlets discolored at the tips, and tending to collapse on pressure on this situation. Then occur plants the roots of which are terminally pale brown, collapsing readily on pressure, instead of being white and resilient . . . this extends upwards along the course of the root. . . then finally we meet with plants in which the roots are all decayed.

"If suckers derived from badly affected plants . . . are planted under certain conditions as regards soil, they will not exhibit the dis-

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[1] Apparently a confusion of top rot with wilt, or else the "wilt" in Queensland has different symptoms than in Hawaii, possibly due to difference in climate.

ease on becoming established, and will, moreover, produce healthy plants . . . the disease occurs quite spontaneously in plantations without any circumstance existing to favor the supposition that it has originated through infection. Further, it cannot be communicated at all or only exceptionally. Again roots may commence to decay in the manner indicated, and then the process stops, new lateral offsets arising to take on the functions of those organs which they replace. Thus it would appear that the inception and continuance of the disease is determined by certain conditions apart from those furnished by the plant itself.

". . . it may be remarked that some of the oldest growers are of the opinion that the pineapple plants, as being the progeny of one stock, are in gradual process of deterioration. . . . As a matter of fact, however, plants from remote localities have from time to time been introduced, yet without such results following their introduction as the advocates of 'new stock' are wont to anticipate.

"Commonly, the disease selects the young plants in preference to the old,[1] and this circumstance is similarly accounted for, also must not be forgotten that the critical period in the life of the pineapple is during the second and third years of its existence.

"When no other conditions obtain which tend to impair the healthy vitality of almost any plant, but especially the pineapple, it may be observed that certain classes of soil especially favor the disease—namely, those in which the water remains near the surface, either (1) owing to its inability to percolate to lower levels by reason of the presence of an impervious subsoil, or (2) too ready connection with lower water-bearing strata owing to some special property in the subsoil facilitating capillarity.

"Thus there are two different classes of soil in which plants subject to the disease occur, a circumstance which has given rise to the opinion that the character of the soil in no way influences its presence. Abundant evidence, however, confirms the opposite conclusion.

"Cultivations in which the disease is general have their soil answering to one of the following descriptions:

"(1) A shallow, sandy loam with clay subsoil.

"(2) Soil of good depth, largely composed of sand, becoming paler downwards and resting on clay.

"(3) A more or less argillaceous[2] shallow soil (18 inches) resting on clay.

"(4) Pale colored clayey loam, but 1 to 6 inches deep, resting on clay.

"The following soils grow pineapples free from disease:

"(1) A reddish brown or red loose deep soil, with or without small ironstones, resting upon an open ferruginous 'cement.'

"(2) A rich open loam, of considerable depth containing little free sand.

"It happens that some of the soils, though when wet weather prevails they determine, owing to their excessive moisture, the presence of the disease, are especially suitable for the growth of the pine, and yield heavy crops in time of drought, and this is especially the case when the impervious clay pan is some depth from the surface. All soils are, however, improved as far as relates to the growth of the pineapple plant by artificial drainage, and diseases will in many cases give place to healthy growth wherever this is properly carried out.

[1] There are plants 30 years old which show no symptoms of disease.
[2] Clayey.

"The conclusion of the whole matter is, then, that the disease of the pineapple plant is caused by a special fungus which lives at the expense of and so destroys the roots—a fungus which is secondary, the injury being primarily occasioned by the soil not being in a condition for healthy growth."[1]

The following remarks are abstracted from an article on pineapple wilt by W. Nowell:[2]

"An affection of pineapple plants occurring on trial plots at Grove Botanic Station, Montserrat, has recently received attention. . . . The plants are of local stock (Ripley) . . . the first indication is a reddening of the foliage, which later becomes strongly marked, and the leaves wither from the tip downwards. More than half of the quarter-acre plot is now affected, and the disease continues to spread. Its progress is not very rapid: The general appearance is that of a slowly progressive drooping and wilting of the leaves, accompanied by a loss of color and ending in the complete drying up of the plant. . . . It is quite certain that the malady spreads to plants adjacent to those first affected. . . .

"In the specimens under consideration there are present in the roots from an early stage of their failure, fungus hyphae occupying the vessels, and the presence of hyphae is referred to by most writers on the subject. Most commonly the fungus referred to is a *Fusarium*. . . . The presence of such fungi on the roots is not of much value as evidence of their pathogenic nature. . . . The evidence which is most suggestive of a parasitic origin for the disease is that with regard to its communication from one plant to another, but in this respect the evidence from different countries is conflicting.

"There are two sets of ideas, more or less opposed, with regard to the nature of this disease. (a) That it is due to infection. . . . (b) That the disease is primarily due to some unfavorable conditions of growth.

"In the case of the beds at Grove Station there is no unfavorable factor apparent. . . . On the other hand none of the specimens examined from 1907 to the present time has revealed the presence of any parasitic organism adequate or constant enough to account for the affection."

Smith[3] states:

"In practice we have reason to believe that a diseased stock will prove a center of infection.

Lucas:[4]

"In a field of Ripley pineapple plants after the wilt makes a start, no matter how small the affected area might be, it will in an incredibly short space of time spread over acres, and in a few months will completely kill every plant, no matter whether the plants are old or young; but this disease seldom allows a plant to become of any age before it completes its work of ruin."

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[1] NOTE:—No experimental evidence is offered in support of the above views by H. T.—(Author).

[2] *In* The Agricultural News, Vol. XV, No. 367. 1916.

[3] Smith, C. E.—Bulletin Botanical Department, Jamaica, IX, 161. 1902. West Indian Bul., IV, 110. 1904.

[4] Lucas, F. L.—Bul. Dept. Agric. Jamaica, V, 41. 1907.

PLATE I.

An early experiment which indicated that the Lahaina disease could be prevented by sterilization of the sick soil by either steam or formalin. It also indicated that bagasse exerted a favorable influence. Tub experiments with sick Waipio soils. Root systems, Lahaina cane, age 3 months. No. 2-3—Natural sick soil. No. 9—Disinfected seed, natural sick soil. No. 12—Disinfested seed, steamed sick soil. No. 5-6—Steamed sick soil. No. 30—Sick soil 63/64 parts; bagasse 1/64 part, by volume. No. 36—Sick soil disinfected with formalin.

According to Nowell, the Red Spanish variety in Montserrat is quite immune to the "wilt" disease, in contrast to the Ripley and all the other members of the Queen family.

Larsen[1] holds the following view:

> "The malady as occurring in Hawaii does not seem to spread from one plant to its neighbor, but appears in a sporadic manner."

Since 1910, however, we have had several sections in which there can be little doubt of spreading, i.e., Kailua section, virgin land and plant crop in 1918–1919, and similar epidemic manifestations in 1919–1920, in various parts of the Islands, indicating a change in nature of the disease.

PART II — EXPERIMENTAL.

Since the publication of the writer's preliminary report[2] on root rot of cane (Lahaina disease), pineapple (wilt) and other crops in Hawaii, the experiments reported therein have been largely repeated, with identical results. During the past six months, while the investigation of the root rot problem has been carried on at this station, further interesting observations have been made.

It will be recalled that upon taking up the investigation of the root rot of cane, the theory was advanced that "Lahaina disease" and pineapple "wilt," as well as several other diseases of Hawaiian crops, were essentially of the same origin and were induced by a fungus allied to the genus *Pythium;* that "Lahaina disease" and pineapple "wilt" diseases were essentially the results of a "damping off" of the roots under suitable soil conditions.

In this section of the paper it is proposed to collect recent miscellaneous observations on the root rot problem which have been recorded in the monthly progress reports, together with a discussion of the present status of the "Lahaina disease" and pineapple "wilt" problems.

Evidence Supporting the *Pythium* Theory.

In order to be convincing, experimental research seeking to establish the fact that a specific fungus causes a certain disease, must satisfy some fundamental requirements. Among the most important of the requirements set up by pathologists in this respect are the following: (1) Constant association of the fungus with the disease in sufficient quantity to make it plausible that the fungus is the cause. Presence of the fungus in and about the healthy tissues at the border of the lesions, and apparent ability of the fungus to attack healthy tissues rather than merely to inhabit dying or dead tissues. (2) Parasitism. Ability of the fungus to produce the characteristic symptoms of the disease when brought by means of pure cultures into contact with susceptible host plants, and inability of other associated fungi to produce the symptoms. (3) The successful reisolation of the specific fungus from the artificially induced lesions of inoculated diseased plants, and the successful inoculation of sus-

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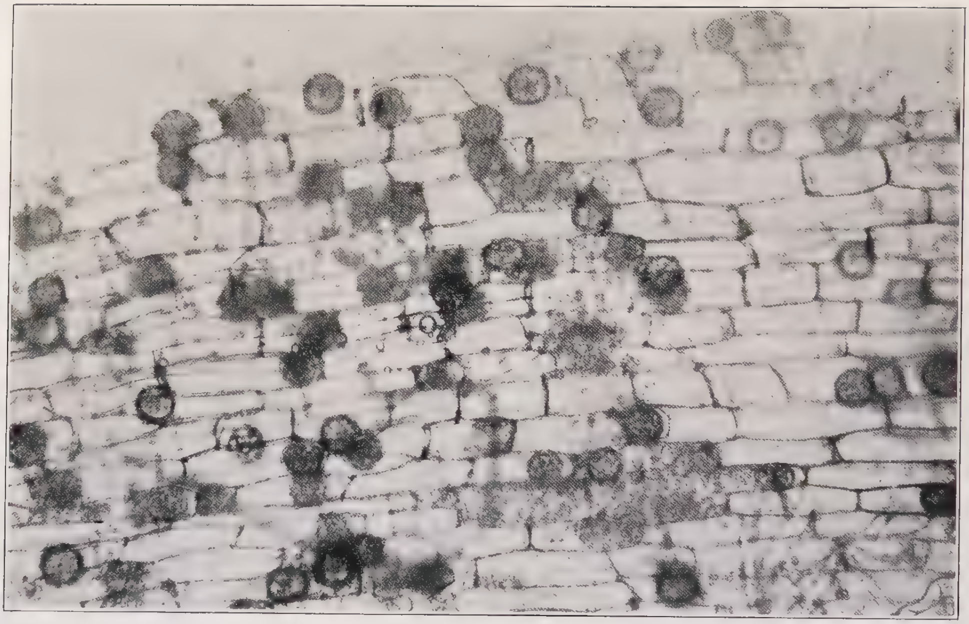
[1] Larsen, L. D.—Pathological Bull. 10, this Station. 1910.

[2] Press Bulletin 54, Hawaii Agricultural Experiment Station, December 9, 1919.



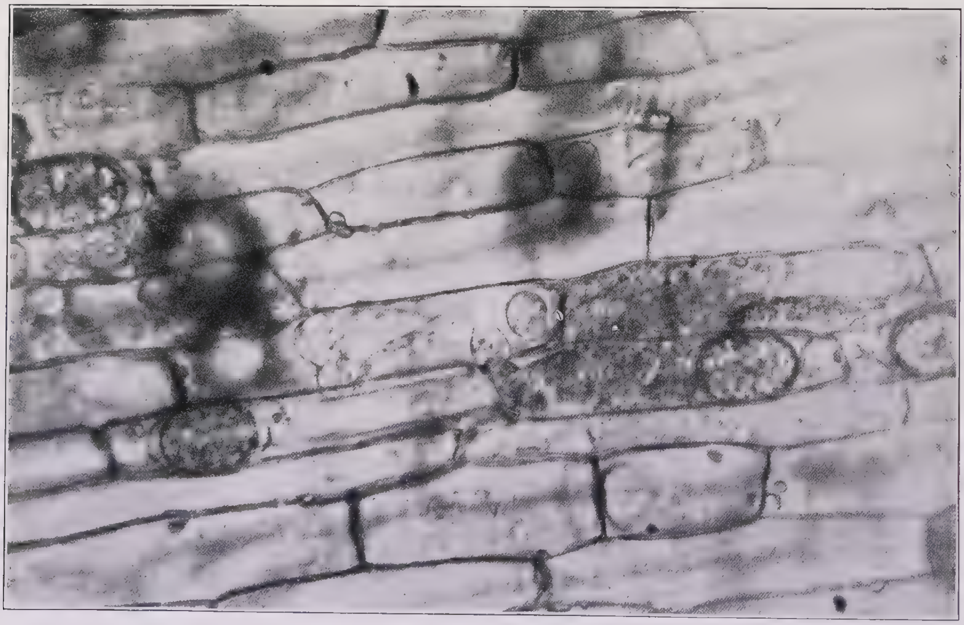


PLATE II.

"Resistant" Demerara 1135. Tip of root showing resting spores and other stages of the *Pythium* type fungus. Soil inoculated.

Fig. 1 ×200 Fig. 2 ×500

Crushed root tips of D 1135 growing in steam sterilized soil inoculated with the *Pythium* from Lahaina cane. Similar results accompanied root injury in H 109 and Yellow Caledonia, indicating that the resistance of these three varieties is relative, not absolute. The large number of spherical resting spores and associated swollen mycelium are illustrated. Such conditions are found in Lahaina cane and pineapples, both in the inoculated soils and in the field.

ceptible plants with the reisolated fungus. The investigation of points (2) and (3) can be prosecuted *ad libitum,* until the investigator himself is assured of the causal relation of the fungus to the disease, and that no other fungus associated with the disease will produce the symptoms under the same artificial environment he may have to set up by the very nature of the problem.

With pathological problems, the extent to which it is possible to meet these requirements varies. Owing to the capricious character of this disease, no satisfactory scheme for inoculation of plants under natural field conditions has yet been devised. As can readily be seen from the following statement of our present knowledge, as demonstrated by the writer's experiments, these requirements have been met sufficiently to warrant further active consideration of the theory, if indeed they do not warrant acceptance of the soundness of our hypothesis. With respect to the requirement, "constant association of the fungus with the diseases," the evidence is still meager. Only extended observations can satisfy this requirement. For reasons given below, it may for a long time be difficult to demonstrate the fact of constant association of *Pythium* with the root rot diseases of pineapple and cane.

Association of Pythium with Lahaina Disease and Pineapple Wilt.

In seeking to locate the possible cause of root failure, which was earlier determined by various investigators to be the fundamental reason for the above-ground symptoms of disease in cane and pineapples, there was little success. Since no parasite could be detected, the diseases have been variously attributed to unsanitary conditions of the soil. This has been interpreted to mean physical or chemical conditions of the soil unfavorable to the plants, such as the presence of injurious chemicals, or plant toxins, or absence of necessary chemical elements, etc.

A working hypothesis which has been drawn up by the writer for further investigation of the problem takes into account the suspected elusive and transient features of the fungus deduced from the capricious occurrence of the diseases. The conflicting history of the diseases furnishes a basis for assumptions which are as follows: (1) The organism is active periodically (cf. temperature considerations, p. 172); (2) the symptoms of disease as observed on the above-ground portions of the plants are manifested after a greater or less time subsequent to actual root failure; (3) and that *at the time* the plant has noticeable symptoms of disease the affected roots are in such an advanced condition of disease that the parasite can be detected, perchance, only after painstaking search, and if present at all *then* is not a conspicuous occupant of the roots. In other words, root failure is not necessarily coincident with above-ground symptoms, but in greater or less degree correlated with the seriousness of the gross symptoms, has preceded the manifestation of the latter by a greater or less period of time.

It is perhaps significant in this connection that with cane symptoms of root failure arouse general interest in the fall months and winter, while with the pineapple, the symptoms are perhaps most alarming in the spring months.

PLATE III.

Lahaina cane, age 4½ months. Sick Waipio soil steam sterilized. At left soil inoculated with *Pythium* type fungus; at right uninoculated control. Three and one-half months after inoculation.

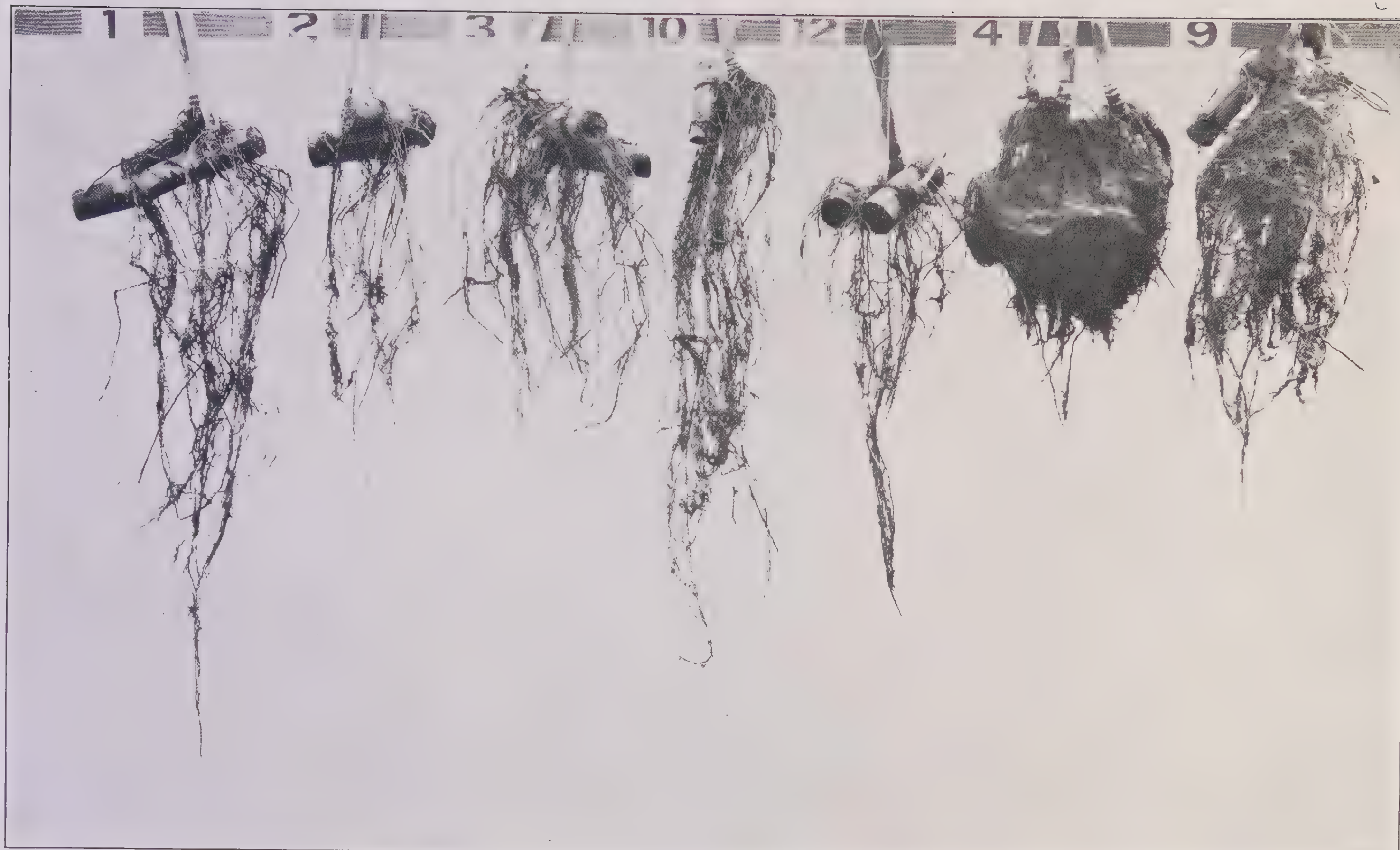


PLATE IV.

Root systems, Lahaina cane, age 4½ months. Sterilized Waipio sick soil.

Fig. 1–2 3–10 12.—Soil inoculated with *Pythium* from cane. Note ragged root system and lack of feeders.

Fig. 4–9.—Uninoculated controls. Note mass of feeders.

PLATE V.

Root systems steamed sick Waipio soil. Closer view of certain figures of Plate IV. Figs. 3, 10, 12, inoculated soil. Fig. 4, uninoculated control. Age, 4½ months. Note mass of secondary feeding roots. The fungus restricts the development of feeding roots, and cuts off the primary roots to a great or less extent.

A partial recovery of little affected plants and checked spreading of the disease in the late spring and summer months is annually remarked.[1]

With both crops, however, the first symptom is checked growth. As to the periods when the damage is done, the writer believes that these occur for the most part in the cooler months of the year: (1) When vegetative vigor is at its lowest ebb; (2) when there is more moisture present in the soil, and soil conditions, particularly temperature, are perhaps otherwise more suitable to the parasite or less favorable to the cane; (3) another critical period is possibly the time when the energies of plants turn from vegetative to reproductive activity, since in the relation of other plants to certain diseases this is a critical time.

From our present data we cannot say that the *Pythium* fungus is constantly associated with the diseases, pineapple "wilt" and Lahaina disease. It is found, however, often enough and under such conditions as to make it seem probable that such is the case.

When the fungus is found in suitable material, roots which are in an early stage of attack, it is sufficiently abundant to account for root failure, and there is ample evidence in the disposition of the mycelium, etc., that the organism is actively invading cell after cell and appropriating the cell contents for its own development. In pot cultures there remains no doubt as to the ability of the *Pythium* type fungus to occupy and destroy the roots of Lahaina cane.

Parasitism of the Pythium Type Fungus from Lahaina Cane.

Positive Inoculations of Sugar Cane.

The symptoms of root disease which appear to be a constant feature with respect to the roots themselves, are a softened and watery appearance, or total collapse of the roots from the growing tip backward, red, canker-like spots on the larger roots at almost any point, ultimately girdling and destroying the cortex of the root, and final softening and decomposition of the central root cylinder or conducting portion beneath the cankered area. The result is a scarcity of secondary or feeding roots, since, under favorable conditions, these are rotted at the end as soon as formed, and an abnormal branching of the larger or primary roots. (Pl. VI.) The tips of these dying, branches form in a cluster back of the decaying end, each root in turn dying at the end, though occasionally one root of the branch group succeeds in escaping infection for some time. These are the characters of root disease of cane one finds in the artificially induced disease in sterilized soils in pots, and also in plants diseased as a result of growing the Lahaina cane in sick soils unsterilized in pots. Similar effects are rather constantly found in field material.

Our observations of diseased Lahaina cane and pineapples from the field where we have succeeded in finding suitable material in the early stages of root trouble, lead us to believe that these are the train of symptoms manifested by the roots in the course of these diseases as they exist in the field. In such

[1] Cf. Planters' Record XII, p. 383, and Figs. 6-7. 1915.

PLATE VI.

Under favorable conditions the fungus attacks the growing tip of the root, preventing further development; branch roots issue and meet the same fate. Primary roots thus checked cannot wander and forage, or develop with wide range to carry the feeders to adjacent fertile situations.

Abnormal branching. Lahaina cane root. The main root and all branches but one are rotted or softened at the growing tip.

material, as well as occasionally in pot cultures, after the roots have practically all become affected by the disease, a few new roots may come out and, curiously enough, show no signs of lesions for a considerable period. It is becoming increasingly evident that it is very important to determine the obscure factors of environment which limit the disease.

Altogether, in the writer's soil inoculation experiments with pure cultures of the *Pythium* type fungus isolated from Lahaina cane roots, some fifty Lahaina cane plants have been inoculated, and subsequent developments, compared with controls, have been watched. These cane plants have been grown in soil sterilized at from 25 to 40 pounds of live steam for one hour. After an incubation period of varying duration the entire root systems have been washed out carefully and comparisons made. (Pls. II to VII.) In no case has there been failure to induce root disease in some degree, and in most cases a very striking difference existed between total roots of inoculated plants and those of control plants identically treated except for the inoculation. In only a few cases were there any root lesions at all on the controls; where there were lesions they were not serious, and not to be definitely determined as of the *Pythium* sort. Dark colored lesions occur in old pot cultures as a result of crowding when the roots come into forcible contact with the side of the pot or struggle to get through the opening in the bottom. Such lesions, while simulating the *Pythium* cankers, are not in general to be confused with them.

In the root tips and lesions of inoculated plants the same evidences of fungus occupancy were found as in field material. The cells were permeated and occupied by fungus mycelium and haustoria-like processes, often in swollen globular form, finely granular and difficult to see at first. Resting spores of the *Pythium* type were present likewise. The latter are often crowded in large numbers in the root tips when collapse commences. (Pl. II.) They are less in evidence in old collapsed roots and it is a question what becomes of them.

To finally prove the theory, it is desirable to inoculate Lahaina cane growing in virgin soil or soil uninhabited by the *Pythium* fungus, thus demonstrating that in the field plants in inoculated soil get the Lahaina disease, while those in uninoculated soils adjacent do not suffer. The evidence of former experiments by other workers with Lahaina cane in virgin soil is such that experiments of this sort do not seem to promise conclusive results. It appears that where the disease *can* occur the conditions are already present, including the fungus, so that if susceptible plants are put in the disease will appear when meteorological and soil conditions are favorable.

We do not know whether the fungus is already widely distributed, or universally present, in our soils, and that the outbreaks of disease accompany favorable soil conditions, or whether, under the same "soil conditions," the disease occurs only as the fungus spreads from field to field.

We must establish the following point:

Does the typical disease occur in the absence of the Pythium type fungus?

It is our impression that when we see the disease, especially in the pineapple, gradually spreading over a field not hitherto observed to have the "wilt," we are merely observing the after effects, the root disease having gone over the same area, possibly months earlier, the fungus preventing the development

PLATE VII.

Showing that natural sick plants and inoculated sick plants are approximately the same size in contrast with healthy control. Later the natural sick plants become larger than the artificially sick plants, probably due to the fact that steamed soils offer a more favorable situation for soil parasites, a fact often noted in the literature.

Lahaina cane. Age 57 days.

Fig. 1.—Sick Waipio soil.

Fig. 2.—Sick Waipio soil sterilized and inoculated one month previously.

Fig. 4.—Uninoculated control, sterilized soil.

of an adequate root system until the advent of other conditions more favorable to the plant. The after effects proceed progressively, following the same general lines as the root disease. It would seem that the fungus is the ultimate limiting factor, rather than the meteorological and soil conditions, since we do have this evidence of spreading. In such cases as are recorded where Lahaina cane and pineapples failed in virgin soil, the parasite has probably been introduced by irrigation water, implements, etc. This is in accordance with the writer's original theory that the fungus determines the disease ultimately, but that it is only active under certain conditions, the two factors being in their interaction responsible for the capricious nature of the diseases. There are two climatological factors which may be the ones responsible for the activity of the fungus. These are rain accompanied by unusually low temperatures; in Hawaii with our equable climate, a few degrees is a usual drop in temperature in the winter months.

With respect to natural factors which bear a relation to infection, severity of disease and seemingly inexplicable recovery, recent investigations by Jones,[1] and Johnson and Hartman[2] on the relations of soil temperatures to plant diseases are significant. Jones cites many instances from various workers and with several diseases which add weight to this phase of the relation between environment and parasitism. He makes the following statement (l. c. p. 230):

> "Thus, for at least two groups of seedling or root-invading parasites, certain smuts and Fusariums, slight variations in soil temperature at critical periods seem to be the deciding factors in possible parasitism."

Johnson and Hartman made a study of the influence of soil environment on the root rot of tobacco. Although this is a different disease, a few statements from their conclusions seem to be of the utmost significance to our problem and are quoted:[3]

> "The root rot of tobacco, caused by *Thielavia basicola,* is marked by the stunting of plants in various degrees, due to a reduced root system. The extent of the damage is determined in a large manner by the environmental conditions surrounding the roots of the host.
>
> "The factors especially studied were the amount of infestation in the soil, the soil moisture, soil temperature, soil reaction, physical structure and fertility. . . . Under normal conditions the end result in injury by root rot is the sum total of the favorable and unfavorable action of these factors on the disease.
>
> *"The temperature of the soil is undoubtedly the most important factor in determining the extent of the root rot of tobacco, other factors being equal. The most favorable temperature for the disease ranges from* 17° *to* 23° *C.* (62.6° *to* 73.40° *F.). Below* 15° (59° *F.) the disease is less marked, and above* 26° (78.8° *F.) the severity is gradually reduced* until at about 29° or 30° (84.2° to 86° F.) it has little or no influence. At 32° C. (89.6° F.) practically no infection occurs even in the most heavily infested soils. Soil temperature records in the field for four seasons indicate that *the occurrence of the disease under practical conditions is determined primarily by soil temperature.*

[1] Jones, L. R..—Soil temperatures as a factor in Phytopathology. *In* Plant World, v. 20, pp. 229–237. 1917.

[2] Johnson, James, and Hartman, R. E.—*In* Journal of Agricultural Research, Vol. XVII, pp. 41–86. 1919.

[3] Fahrenheit temperatures and italics, the writer's.

PLATE VIII.

Response to copper sulfate. (Compare with Plates IX and X.)

The plant in pot 3 gained over the plant in pot 2, when watered for one month with 1–50,000 copper sulfate solution.

Copper sulphate 1–100,000 apparently had no effect in the same time, cf. Plate X.

Pot 3 received 12 applications of 750 cc. each of 1-50,000 copper sulfate during the month, i.e. approximating .18 grams of c.p. copper sulfate was applied to the soil of the 12-inch pot. Other pots, same amount of water.

Fig. 5 showed no increase in size over Fig. 4 of Plate IX, both being uninoculated controls; Fig. 4 receiving no copper sulfate, and Fig. 5 receiving the same amount as Fig. 3. *It is obvious that a controlling effect on the fungus is indicated here, and not merely a stimulating effect on the plant.*

Cf. Planters' Record, June, 1920, for response of Lahaina cane to "Qua-Sul."

Lahaina cane, age 84 days.

(Fig. 2 and 4 same as in Plate VII, one month later.)

Fig. 2.—Sterilized sick soil inoculated.

Fig. 3.—Sterilized sick soil inoculated; watered past 27 days only with 1–50,000 copper sulfate.

Fig. 5.—Sterilized soil, uninoculated control. Watered with 1-50,000 copper sulfate past 27 days.

> "Field observations and limited laboratory experiments seem to show that infested soils when compacted are more favorable for the disease than loose, open soil."

Considering these observations on the determining effect of temperature on plant diseases, there is support for the theory of a parasitic origin of Lahaina disease in the following quotation from Agee.[1]

> "There is perhaps no influence that contributes in a greater degree to the failure of Lahaina cane than the cool weather of our winter months. Time after time it has been noted that Lahaina planted in June or thereabouts will come to a good stand and grow vigorously until about October. At this point in many cases growth appears to cease entirely. The plants struggle along, putting out a few new roots to replace those which are rotting away. Finally the top may rot off if conditions reach their worst, or the second summer may, particularly if there are rains, bring about a renewed growth. Oftentimes, however, the cane does not succumb at the first cool days. Its growth is checked very gradually. Then there appears a series of abnormally short joints and later it may either resume average growth or continue stunted."

Positive Inoculations of the Pineapple.

Such inoculations of pineapple plants as have been made with the *Pythium* type fungus isolated from Lahaina cane resulted in stunting of the plants compared with uninoculated controls. (Pl. XIII.) The pineapples were grown in sterilized soil in twelve-inch pots. Other wilt symptoms, such as yellowing, narrowing and twisting of the leaves and lack of normal turgor, while not strikingly present, nevertheless were detected. Roots of inoculated plants showed characteristic inhabitation of the cells by the fungus such as has been seen in field material and such as is characteristic of the cane material, both naturally and artificially diseased.

Recently a successful isolation of a *Pythium* type fungus was made from a pineapple "wilt" plant from Kailua, Oahu. This plant was placed in water, and after a few days new roots came out among the old roots. These new roots finally collapsed and numerous spores, mycelium, etc., were detected with the microscope. A *Pythium* type fungus was then isolated. Should this prove to be a parasitic strain for the pine, a distinct step as far as "wilt" is concerned will have been made. Inoculation tests with this fungus are under way.

Reisolation of Pythium Fungus.

In a large number of cases, and in fact in practically all the attempts made, the writer has been successful in reisolating the used fungus. In the only attempt made such a reisolated strain of the fungus from artificially induced root rot again produced the disease upon inoculation of cane in sterilized soil. This type of work, soil inoculation and reisolation of the fungus from root lesions, was continued until it seemed conclusive to the writer, but some further work along such lines will be done.

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[1] Planters' Record, Vol. XII, p. 383. 1915.

PLATE ~~IX.~~ X

Response of plants to 1–50,000 copper sulfate, and lack of response to 1–100,000 copper sulfate. Cf. Plates VIII and IX, and caption Plate VIII.

Steam sterilized sick Waipio soils. Inoculated, and watered with copper sulfate.

Fig. 3.—Inoculated with *Pythium*. Watered past month with 1–50,000 copper sulfate solution.

Fig. 12.—Same as Fig. 3, but watered with 1–100,000 copper sulfate solution.

Fig. 13.—Uninoculated control, watered with 1–100,000 copper sulfate solution.

Certain additional observations indicate that the root rot of Lahaina cane and pineapples is of parasitic origin. Lahaina cane in sick soil sterilized by means of either steam or formalin developed a healthy root system in contrast to cane in unsterilized sick soils. (Pl. I.) The disease appears to spread in the fields with considerable rapidity, both in pineapples and cane. Likewise the diseases are periodic and somewhat seasonal in their occurrence. In cane some varieties, such as H 109, D 1135 and Yellow Caledonia, are markedly resistant under field conditions, though they do in restricted areas in the fields show the characteristic symptoms of the disease, together with root failure and root lesions with associated mycelium and resting spores of the *Pythium* type.

Negative Inoculations with Other Fungi.

As additional or contributory experimental evidence bearing out the *Pythium* theory the negative results of inoculations with pure cultures of other fungi may be cited.

Inoculations of Lahaina cane have been made with pure cultures of the following:

1. *Pythium debaryanum* from damping off of sugar beets. Courtesy of U. S. Dept. of Agriculture.

2. *Rheosporangium aphanodermatus* type. Isolated from roots of Lahaina cane. At first considered identical with the writer's *Pythium* strains. Culture studies resulted in the development of presporangia and zoospores.

3. *Fusarium.* Of this genus, from a large number of cultures, two species which belong to parasitic types were selected for tests. One, No. 295 A., resembles *Fusarium herbarum* (Corda) Fries, related to or synonymous with *F. pirinum* and *F. putrefaciens.* The other, No. 314 F., is an *Elegans* type, suggesting *Fusarium oxysporum* (Schlecht.) Smith.

4. *Meliola* or *Capnodium.* The *Capnodium,* or sooty mold fungus, which is a conspicuous superficial occupant of canes; when dry it gives a smoky color to the cane.

5. *Rhizoctonia* sp. A species of *Rhizoctonia,* No. 23 A., was isolated from the roots of affected cane; its counterpart, with regularly constricted mycelium, is often seen occupying the surface cells of roots of diseased cane plants.

The above fungi, *Pythium* from sugar beet, and *Rheosporangium, Capnodium, Fusarium,* and *Rhizoctonia* sp. from cane, all failed to produce symptoms of root disease, and no lesions could be found which indicate that they are parasitic in any significant degree. (Pls. XI, XII.) In parallel comparative soil inoculations with the parasitic *Pythium* from cane, positive results were strikingly obtained. (Pls. III, VII.) All tests were made by inoculation of the steam sterilized soil.

The Pythium Type Fungus.

The life history of the *Pythium* found parasitic on Lahaina cane in pots is not yet worked out. There are points in its morphology necessary to determine before the fungus can be satisfactorily classified. Therefore, it is best called the *Pythium* type fungus for the present. If it forms zoospores, free

PLATE IX.

(Compare Plate VIII.)

Lahaina cane; age 84 days.

(Fig. 2, same as Plate VII and Plate VIII. Fig 3, same as in Plate VIII.)

Fig. 2.—Sterilized sick soil inoculated with *Pythium*.

Fig. 3.—Sterilized sick soil inoculated with *Pythium*. Watered past 27 days only with 1–50,000 copper sulfate.

Fig. 4.—Sterilized soil, uninoculated, untreated.

swimming asexual spores, their mode of formation and liberation will indicate to what genus the fungus belongs. No zoospores have been found in pure cultures, though such spores have been seen in diseased material; whether they belonged to this *Pythium* type fungus or to some related saprophytic fungus could not be determined. A description of the fungus will not be attempted until further morphological studies have been made. The illustrations in the writer's preliminary report show some significant features of the fungus with which we are concerned.

The Genus Pythium.

The genus *Pythium* is a small group of primitive fungi, sometimes included with the Saprolegniaceae and sometimes with the Peronosporaceae. The genus is best known by the representative plant pest *Pythium debaryanum,* a common seedling parasite, cause of "damping off." The group includes both aquatic and terrestrial forms. The absence of chlorophyll is the main distinguishing point between these primitive fungi and some of the algae.

The usual point of attack in the "damping off" disease of seedlings is at or near the surface of the ground. The effects are evident a few days after the seedlings come up, the tender tissues, being occupied by the mycelium of the fungus, lose their turgidity and the plant topples over. While *P. debaryanum* is most common as a greenhouse pest, "damping off" also occurs in the field. Among other plants attacked by *P. debaryanum* are corn and other members of the grass family. *P. Butleri*[1] is recently described in India as a parasite on papaya (foot rot), tobacco (damping off) and ginger (rhizome and foot rot). The *Pythiae* appear to occupy the soil as frequently as they do water, and are in exceptional cases found causing diseases of the aerial portion of plants (*P. palmivorum* Butler, said to cause top rot of palms).

Besides the delicate mycelium, the *Pythiae* form asexual swimming spores and sexual resting spores. Sporangia empty their contents as free swimming zoospores, or germinate directly, in which case they are called conidia. Some of the terrestrial species appear to have lost the power of zoospore formation. They are not readily detected in *P. debaryanum,* in pure culture, and thus far the writer has failed to detect them in pure cultures of the cane fungus. Until the method of zoospore formation is determined, if such are formed at all, this fungus cannot be satisfactorily placed in its proper genus. The sexual spores, or oospores, are thick-walled spherical spores, adapted to carry the fungus through adverse conditions. Such oospores formed in pure cultures of the fungus from cane, agree closely in size with the similar spores in the roots of diseased cane and pineapple, and correspond to published measurements of species of *Pythium.*

PART III—THE PROBLEM OF CONTROL.

If Lahaina root failure and pineapple "wilt" are caused by a fungus of the *Pythium* type, we should ultimately be able to find a practicable means of controlling these diseases. First it is desirable that growers cooperate in furnishing us as complete records as possible on the occurrence of the disease, seasonal his-

[1] Subramaniam, L. S.—*In* Memoirs Dept. Agric. India, Vol. X, pp. 180-194. 1919.

PLATE XI.

Negative inoculations with *Rheosporangium aphanodermatus* type fungus from cane. Steam sterilized soil.

R. aphanodermatus occurs on sugar beets. This type of fungus is readily mistaken for *Pythium* sp. unless zoospores are detected. The fungus here used was isolated from Lahaina cane roots at Waipio, and was mistaken at first for the *Pythium* type fungus. No evidence of parasitism was found.

Fig. 15, 6.—Soil inoculated with *R. aphanodermatus* type fungus.

Fig. 7.—Uninoculated control.

PLATE XII.

Negative inoculations with sugar beet *Pythium*.
Steam sterilized soil. Age 3 months.
Fig. 9–18.—Inoculated with *Pythium* from sugar beet.
Fig. 14.—Uninoculated control.

tory, weather conditions, etc. Against these records the writer's present impressions, which are given below, can be checked so that control experiments may take due account of the relation of weather conditions to the inception and duration of disease.

It seems to be agreed that the symptoms of pineapple "wilt" are most alarmingly prevalent in the spring months. Similarly the Lahaina root disease, or crop failure, is most strikingly prevalent in the autumn and winter months. It appears possible to the writer that both diseases begin simultaneously, but in the cane the effect of a crippled root system is sooner apparent in checked and abnormal growth, while in the pineapple several months during the wetter part of the year are required to show alarming above-ground symptoms. Both crops in our experience recover in some degree by June and subsequently. In cane the joints lengthen out, and in the pineapple, plants not too far gone freshen up, and the spreading of the disease is checked.

If this impression as to the seasonal character of the diseases is correct, chemical and other control treatments should be concentrated in the period from September or October through the cool weather, rather than applied hit or miss at the time experiments are put in, when likely as not the chemicals are all used up or are relatively inactive elements when most needed.

The writer's note on a possible control of the root rot of the two crops by chemical means, in the June Record, 1920, indicates that it may be practicable under field conditions to apply to the soil in the irrigation water sufficient of a specific chemical to check the parasite without being toxic to the host plant. (Pls. VIII, IX, X.) The range between the two effects will probably be small, but experiments along this line are being continued.

With cane, the resistant variety H 109 is gradually supplanting Lahaina, but since this variety, as well as others, takes the root disease in some degree it is desirable that we solve the root rot problem. It is likewise desirable since varieties which are standard for a period of years are said to degenerate. If degeneration is the same in other varieties as in Lahaina, a natural or acquired susceptibility to root rot, it will be very advantageous to know the exact conditions which a variety finally becomes unable to endure.

Should applications of chemicals to the soil be proved desirable in combating the root disease of pineapples, they can be sprinkled on the soil in advance of the cool, rainy season in solution, and theoretically at the time needed will be carried down about the roots by the rain. Whether rain favors the disease or the reverse is not known, and with this, as with numerous other features of the obscure problem, we have contradictory evidence.

As stated elsewhere, the criterion of a successful treatment is gain in yield of treated affected areas over untreated affected areas. Improvement as a result of treatment, where adequately checked by control plots, is encouraging, but with a problem of this sort, in order that such improvement may not be confused with seasonal improvement and erratic occurrence of the disease, considerable time must elapse before any treatment can be said to be successful. The treatment must be more than a stimulant which encourages root development for a short time; it must in some degree prevent the plant losing its roots in the first place. Secondary roots die off anyway after a time, but the writer

PLATE XIII.

Pineapple plants and the *Pythium* from cane.
Steam sterilized soil. Plants 11 months old.
At left, soil inoculated 1 month after planting with *Pythium* type fungus from cane.
At right, uninoculated control.

is persuaded by the evidence that both crops under discussion lose both primary and secondary roots altogether too rapidly at times for this to be a normal occurrence. The effect of the disease is so profound to a fundamental part of the plant that a successful treatment in my judgment must be preventive rather than curative.

PRESENT STATUS OF THE PROBLEM IN BRIEF.

1. Lahaina disease and pineapple wilt are essentially of the same origin and are the result of damping off of the roots.

2. The resistant varieties, Yellow Caledonia, Demerara 1135 and Hawaii 109, take the disease in some degree. Apparently the resistance is relative, not absolute.

3. The "damping off" or rotting of the roots is caused by a specific fungus of the *Pythium* type.

4. The fungus is active only periodically and under certain environmental conditions.

5. From our observations, and the literature of other diseases, by analogy, the controlling factor in the activity of the fungus is soil temperature. The period of active damage to the root systems appears to be limited in general to the cooler months, i.e., October to April. Soil reaction is also a factor of some importance.

6. Chemical applications to the soil and other measures for control should be applied for action in the corresponding period.

7. The treatment must be largely preventive, owing to the profound results of loss of the root system. So far as the individual root is concerned the treatment must entirely prevent softening of the growing tip, since with a dead tip growth cannot be resumed.

8. Pot experiments indicate that we shall be able to control these diseases by chemical applications to the soils.

9. The promising chemicals thus far tried are "Qua-Sul"[1] lime-sulphur and copper sulphate 1/50,000, in the order named.

10. Resting spores of the *Pythium* type have been found in the roots of cane on the Islands of Oahu, Kauai, Maui and Hawaii.

11. Resting spores of the same general type have been found associated with their appropriate mycelium in the roots of Chinese banana, taro, and rice. In the banana the spores suggest a *Phytophthora* rather than a *Pythium*.

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[1] A soluble sulphur-carbon-soda patented preparation. (Cf. Pl. Rec., June, 1920, p. 350.)

Horizontal Tubular Boiler Settings and Details of Installation.*

By H. E. Dart.[1]

Our Engineering Department is now engaged in making new drawings of setting plans for horizontal tubular boilers. In past years there has been a big demand for such setting plans and some of the tracings for the more common sizes of boilers are literally worn out. In making the new drawings, advantage is taken of the opportunity to show certain features in greater detail than was formerly the case and the scope of the plans has also been extended so as to include typical methods of piping and the proper manner for installing the usual fittings and attachments. Figures are also given to show the quantities of bricks required for setting the boilers in accordance with the plans. For each of the common sizes of boilers, it is the intention to make four drawings, two with overhanging fronts and two with flush fronts, one of each style showing boilers suspended independently of the setting walls and the other showing boilers supported by means of brackets resting on the walls. The complete set of plans is not yet finished, but drawings are ready for many of the ordinary sizes of boilers and blueprints can be furnished from such drawings as are finished. Requests for such blueprints should be made preferably through the chief inspector of the department in which the boilers are located (see list of departments on back of The Locomotive) rather than directly to the Engineering Department, because our chief inspectors are familiar with the conditions which exist and are generally able to submit the data which we need to determine which drawing is best adapted to each particular case.

The most important features in connection with the new setting plans are described below. While many of the features mentioned will apply equally well to the design of settings for any other type of boiler, it should be remembered that this description is concerned primarily with hand-fired horizontal tubular boilers using coal for fuel, and is written from that viewpoint.

Wall Construction.

On our old setting plans the outside walls are shown as indicated by Type I, Figure A, but on the new plans we are showing all of the four types of construction described in Figure A, leaving it to the boiler owner to make his choice between these designs. Complete dimensions are given on the drawings for each type of construction.

The design shown by Type I involves the construction of two separate brick walls, bonded solidly together for a distance of about sixteen inches at the top and at the bottom, but separated by an air space two inches wide for the remainder of the height. It is thought by many people that this air space acts as a heat insulator, but such is not the case; experiments by the Bureau of Mines

* The Locomotive. The Hartford Steam Boiler and Insurance Co, April, 1920.

[1] Superintendent of Engineering Department; The Hartford Steam Boiler Inspection and Insurance Co.

have shown that a wall of this type will transmit just as much heat under given conditions as a solid wall of the same total thickness. As regards air leakage into the furnace, however, the double wall with air space has a distinct advantage over the solid wall shown by Type II because the cracks will occur principally in the inner wall, leaving the outer wall intact. With a solid wall, the cracks will extend clear through the brickwork, thus greatly increasing the probability of air leaks and thereby decreasing the efficiency on account of excess air. Not long ago we had occasion to make an examination of a solid-

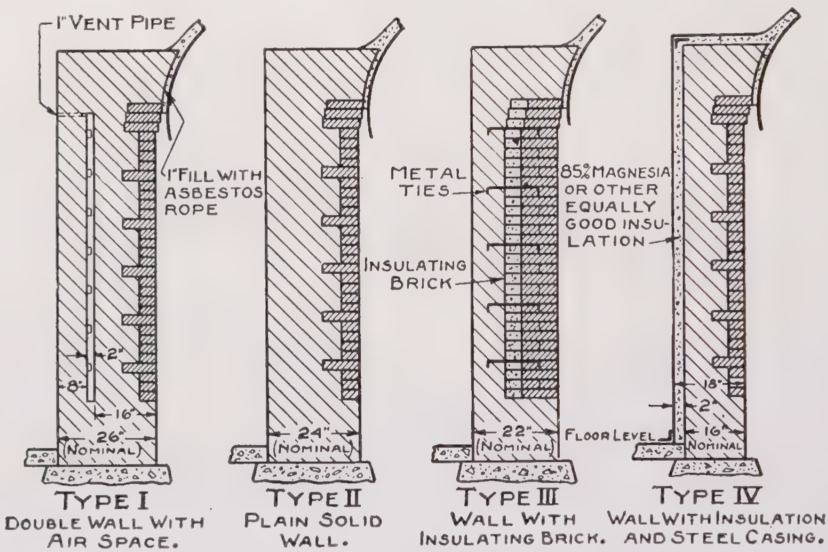

Fig. A.—Different Types of Construction for Setting Walls

wall setting which had been built in the same boiler room with two older settings of the air space type. Although the new setting had been in use only a few months the test with a candle flame showed more leaks than were found in the other settings which had been used several years. Of course such a test is not entirely conclusive, since there are other features which should be considered, but we believe it gives a fair indication as to what may be expected in the average case. In constructing setting walls with an air space it is advisable to insert a few ventpipes as indicated in the cut, these pipes being especially desirable if the bricks contain much moisture when they are laid. After the setting has thoroughly dried out, all ventpipes should be permanently sealed so as to prevent air leakage into the setting and heat radiation from the inner wall.

Type III in Figure A makes use of insulating bricks to reduce the amount of heat that is transmitted through the wall and thereby lost. These insulating bricks are made of different materials by different manufacturers and they are cut to the proper size to lay up evenly with ordinary bricks and fire bricks. They have little mechanical strength in themselves, so that it is best to use metal ties, as shown in the cut, for bonding the inner firebrick section to the common brick on the outside. It is also advisable to use a uniform thickness of nine inches

for the firebrick lining in place of the 4½ inch lining with headers as shown for the other types. This type of construction makes a very good setting, costing somewhat more than either Type I or Type II.

Type IV is similar to Type I with a steel casing substituted for the outer wall and the air space filled with magnesia or other good insulating material. This makes a most excellent form of setting, the only drawback to its more general use being its greater cost as compared with other types. The insulating material reduces the heat radiation loss to a minimum and the steel casing prevents the even greater loss due to air leakage through the setting walls. Furthermore, a setting of this kind presents a very neat appearance and requires less space than any of the other types illustrated, there being a saving of eight inches in length and sixteen inches in width as compared with Type I. Number 8 U. S. gage steel plates should be used for the casing with angle irons placed about 3½ feet apart along the sides and back and with similar angles at the top, bottom, corners and elsewhere as needed for stiffness and stability.

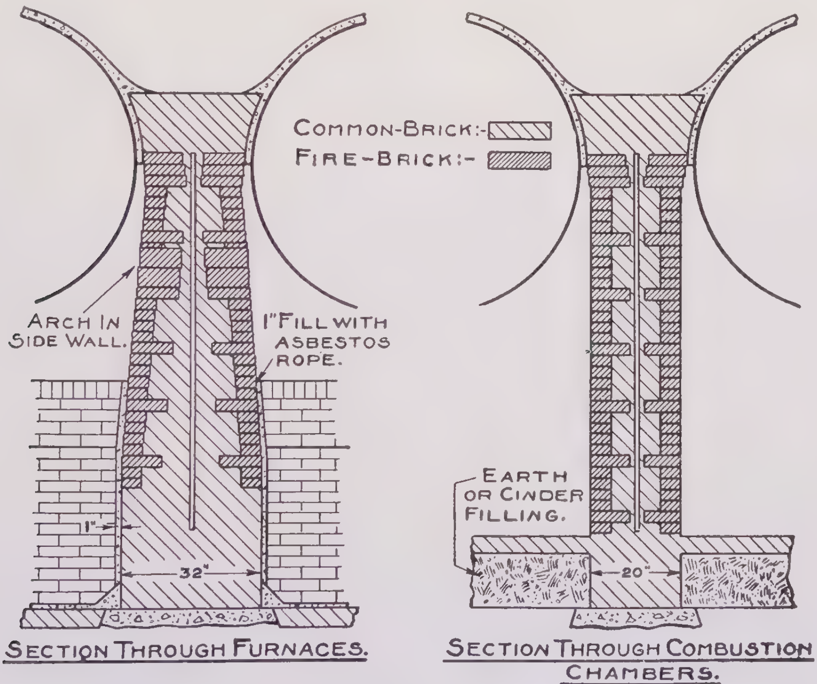

Fig. B.—Division Walls Between Boilers Set in Battery

For the division walls between boilers set in battery the style of construction shown in Figure B is satisfactory, regardless of what type of construction is used for the outside walls. The vertical slot shown in the center of the wall does not indicate an air space like that in Type I, but is intended to show that the two walls should be built separately and not bonded together in the center. This is advisable to make allowance for expansion when there is a fire on only one side of the wall.

The sections in Figure A apply to the side walls at the rear of the bridge wall. For the furnace section in front of the bridge wall, we advise that the

walls be battered from the grate level to the closing-in line near the middle of the boiler shell. Our drawings show a batter of six inches in this height, thus making the walls that much thicker at the bottom. A reference to Figure B will make this point clear. The section at the left shows the battered wall while that at the right shows the straight form which can be used back of the bridge wall. This figure shows sections for the division wall between boilers, but the same idea should be applied to the outside walls.

In constructing side walls and division walls it is a good idea to build an arch in the firebrick lining at a height of about three feet above the grates, as illustrated in Figure C. When it is necessary to replace firebrick this arch supports the brickwork above and prevents it from falling down.

For construction like that shown in Types I, II, and IV, where the firebrick lining is only 4½ inches thick, headers should be used for every fifth course or even more frequently. In all firebrick work the joints between the bricks should be made just as thin as possible. For this reason a trowel should not be used, but the bricks should be dipped in thin fire-clay and then rubbed down into place so as to make "brick-to-brick" joints.

Allowance for Expansion and Prevention of Air Leaks.

Ample provisions should be made throughout to allow the boiler and the setting to expand without cracking the brickwork or opening up places where air can leak into the setting. If the brickwork is built tight up to the boiler shell at the closing-in line, cracks are sure to develop when the boiler is heated up and there will also be an opportunity for air to leak in between the boiler and the brickwork. It is best, therefore, to leave the brickwork about an inch away from the boiler and fill this space with asbestos rope or some similar material, as illustrated in the different sections of Figure A. In a similar way, the brickwork and the ironwork of the boiler front should be kept about ¾ inch away from the boiler shell (and concentric therewith) and this space should be filled in with asbestos rope. To prevent cracking due to endwise expansion of the bridge wall, it should be built separately from the side walls, leaving a space of about one inch at each end. This space should be filled with asbestos rope to prevent the accumulation of ashes which would become solid and nullify the advantage to be gained by building the bridge wall independently of the side walls.

At the rear end of the boiler, a space of about 1½ inches should be left between the boiler head and the brickwork; this space can best be sealed against air leakage by extending the insulating covering down over it as shown in Figure C. There is a tendency for the covering to crack open at this point as the boiler expands and contracts, but this difficulty can be largely overcome by the use of a piece of sheet iron, formed to fit over the rear end of the boiler shell and bent down over the head to extend out on top of the brickwork. With the piece of sheet iron in place under the covering the probability of cracking is lessened and, if a crack does develop, the sheet iron will tend to prevent air from leaking into the setting. We advise the use of insulating covering for the boiler top instead of the brick arches which are sometimes used. The covering is a better heat insulator and it can be removed and replaced more readily in case repairs

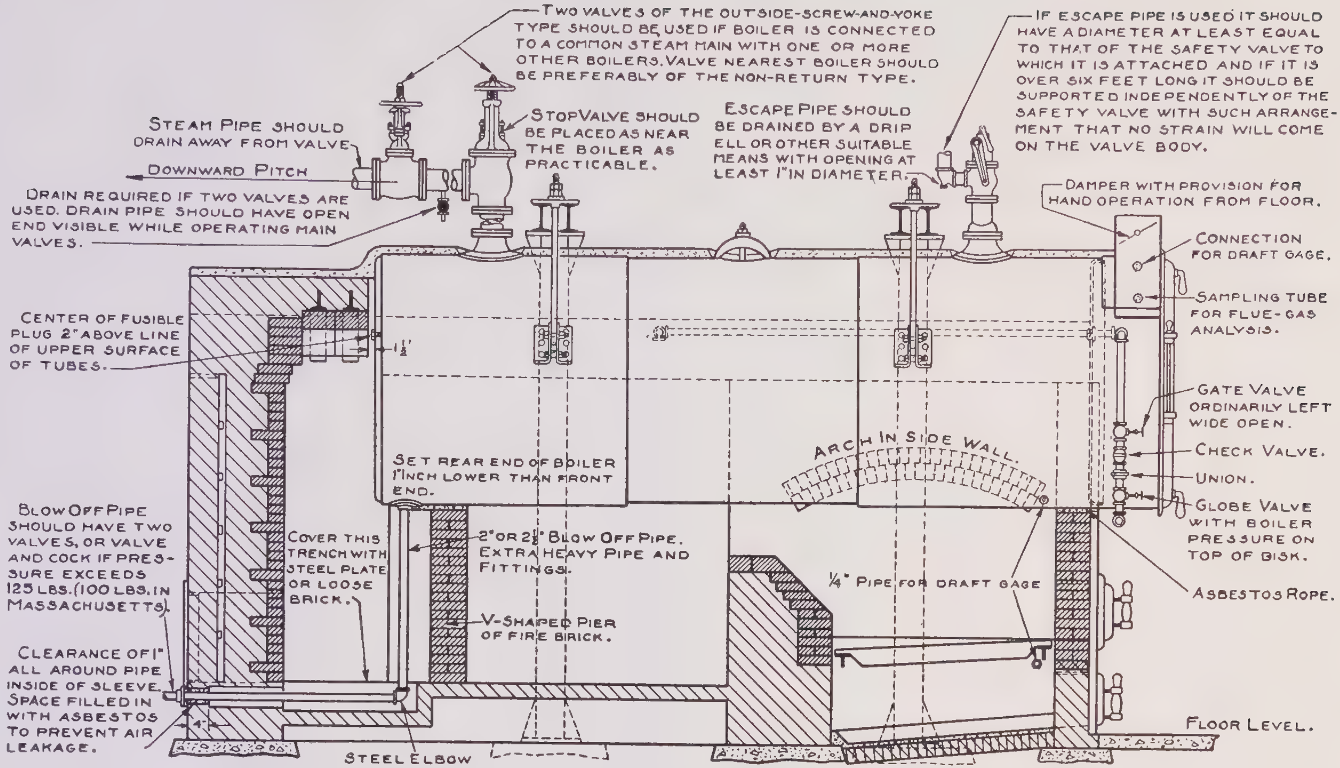

Fig. C.—Longitudinal Section Through Center of Setting.

or inspections of the boiler shell are required. The covering can best be applied in the form of blocks which can be held in position with mesh wire and then finished with plastic magnesia or other insulating cement to make a smooth finish and fill the joints between the blocks. A harder surface can be secured by using a little Portland cement in the final coat. The total thickness of the insulation should be at least two inches.

The loss due to excess air is generally greater than that from any other cause in hand-fired boilers of the type under consideration, and it is also the most difficult to prevent because it is such an intangible sort of thing that the firemen cannot be made to realize its importance. Much of this excess air leaks in through the setting walls and efforts to prevent such leakage by the methods outlined above will be well repaid. It is not sufficient merely to construct the setting as described, however; inspections and tests should be made at frequent intervals to be sure that the asbestos remains in place and that the joints are properly sealed at all points. We have made a number of investigations of this kind and we almost invariably discover air-leaks at some of the places mentioned above as well as around blow-off pipes, firing doors, clean-out doors, etc.

There are several different paints and coatings on the market which can be used to good advantage in the prevention of air leaks. Such compounds are usually composed of asphalt, asbestos and other materials, combined to produce a thick, elastic coating which will stretch without cracking as the setting expands when it is heated up. The coating is usually applied to the entire surface of the setting, care being taken to work it into all cracks, joints and openings around door-frames, boiler fronts, or other similar places. A very satisfactory home-made substitute can be prepared to take the place of the commercial compounds.

Protection of Blow-off Pipes.

The proper protection of the blow-off pipe is an important feature in connection with any setting for a horizontal tubular boiler. There are many ways of providing such protection and in making a choice between different methods one important principle to be kept in mind is that the pipe should be easily accessible for inspection. For this reason a simple pipe sleeve around the blow-off pipe is not satisfactory because such a sleeve cannot be removed without disconnecting the blow-off pipe. Split sleeves of cast-iron are better, but it is usually rather difficult to remove them after the connecting bolts have been exposed to the heat and flames. Several patented styles of blow-off covering are available and these give good results as a rule. In general, such blow-off coverings are made of some refractory material and applied in sections with an interlocking arrangement so that they are easily removable.

Except under extraordinary conditions, the method of installation shown in Figure C provides ample protection for blow-off pipes. The principal features of this method are a V-shaped pier of firebrick which prevents the flames from impinging upon the vertical portion of the pipe, and the location of the elbow in a covered trench where it will be well protected. Blow-off pipes are more liable to fail at the elbow than at any other point and the location of the

elbow in this position is therefore highly desirable. The best arrangement is to build the bottom of the combustion chamber at a somewhat higher level than the boiler-room floor so that there will be space enough to install the blow-off valve or cock without cutting into the floor. It is advisable also to locate the cleaning door at one side of the center, where there will be no interference with the blow-off valve when the door is opened. Plenty of space to permit freedom of movement, due to expansion or settlement, should be left around the pipe where it passes through the setting wall. For this purpose a pipe sleeve about four inches long should be built into the brickwork at the outer end, but a larger opening can be left around the pipe through the remainder of the wall thickness, without any sleeve. The sleeve should have a diameter 2 inches greater than that of the blow-off pipe and it should be filled with asbestos to prevent air leakage. A set-screwed collar on the pipe makes a good finish against the brickwork together with provision for a gasket of sheet asbestos or other suitable material to more thoroughly seal the opening against air leakage. The V-wall should be left a little below the boiler shell to allow for expansion and settlement, and the space should be filled with asbestos to keep the flames from impinging upon the flange where the pipe is connected to the boiler. Blow-off valves should always be located so that there will be ample opportunity for a man to get away in case of a break in the blow-off piping while he is operating the valves.

Arch bars.

The rear arch-bars shown on our setting plans and in Figure C are of the so-called "Hartford" type, designed by this Company several years ago. Bars of this type extend transversely of the setting, spanning its width and bearing upon the side walls. Except for large boilers, only two of these arch-bars are needed for a single setting, but a different pattern is required for each size of boiler. In some sections of the country the "quadrant" type of arch-bar is more popular and it is just as acceptable; this style of arch-bar is made in the form of a quadrant or ninety-degree arc of a circle. The bars rest on the rear wall, arching over to the rear head, and some means must be provided to support the upper ends, so as to permit the boiler to expand without developing air leaks. Several of these bars are needed for a single setting, the exact number depending upon the diameter of the boiler, but the same pattern can be used for all sizes of boilers where the distance from the rear head to the rear wall of the setting is the same. Both types of arch-bar described above are so designed that the metal is protected by the firebrick and not exposed to the action of the flames and hot gases; this feature should be a requirement in the design of any arch-bar.

Arch-bars should be set so as to leave a full, free opening through all the tubes, with proper provisions for inspecting and removing the fusible plug, but at the same time, care should be taken that no part of the head above the lowest permissible water level is exposed to the heat. We recently heard of a case where a head was burned, due either to poorly designed arch-bars or to placing the arch-bars so high as to expose the upper part of the head to extreme heat.

Grates.

We believe that there is a general tendency to use larger grates than necessary with hand-fired boilers of the horizontal tubular type, and this belief is borne out by our experience in several cases where we have found that coal was being burned at a rate of ten to twelve pounds per square foot of grate area per hour, whereas better results would be obtained with a rate of fifteen to twenty pounds of coal per square foot per hour. In some cases we have advised blanking off the rear part of the grates by covering them with firebrick, and a gain in economy of coal consumption has been secured in such cases. Furthermore, it has been common practice to use the same size of grates for a given diameter of boiler, regardless of the tube length, though it is obvious that if a certain area is proper for a boiler eighteen feet long it would not be correct for a sixteen-foot boiler in which the heating surface would be about 11 per cent less. Assuming an evaporation of about 9 pounds of water per pound of coal, the ratio of heating surface to grate area should be about 40 to 1 in order to develop the full rated capacity of a boiler when burning coal at the rate of fifteen pounds per square foot of grate per hour. In designing our new setting pans we have used this ratio to determine the grate area, within the limits imposed by commercial standards as regards length of grates. Provision for overloads and allowance for a lower rate of evaporation can be taken care of by burning the coal at as high a rate as twenty pounds per square foot of grate per hour, this rate being attainable with proper draft and good firing methods. On the other hand, many horizontal tubular boilers in small plants are never operated at their full capacity, and in such cases the grate area could be even smaller. It is fully realized that a larger grate area may be desirable in certain special cases, but it is believed that the ratio of 40 to 1 will give good results for the average case and, of course, this is all that a set of general plans can be expected to cover; special cases should be considered in the light of all the data available in each instance.

With battered furnace walls, as described in the foregoing, the width of grates will be six inches less than the boiler diameter, while with straight walls, as frequently used, the grates have a width equal to the diameter of the boiler. As explained above, the grate area is generally larger than it should be and the smaller dimension for width is therefore generally satisfactory. For the sake of simplicity and uniformity, stationary grates are shown on all of our setting plans, but we recommend the use of shaking grates under ordinary conditions.

Height Above Grates.

Remarkable savings in fuel consumption have been claimed in many cases as a result of setting horizontal tubular boilers at extreme heights above the grates, but, as a general rule, these claims do not seem to be fully substantiated, because all of the credit for any increased efficiency is laid to the greater height of furnace, whereas there are usually other factors which should also receive consideration. In a typical case of this kind, a new boiler is installed in a plant where there are one or more older boilers, and perhaps the new boiler is set at a height of 5 feet above the grates while the corresponding height of the old

boilers is only 28 inches. More or less careful tests are made and it is found that the new boiler is more economical in coal consumption than the old ones. It is then almost invariably assumed that the gain in economy is entirely due to setting the boiler at a greater height above the grates; although the old settings may be twelve or fifteen years old and full of cracks and openings which permit the entrance of a large percentage of excess air, while the new setting is tight, this fact is completely disregarded. Furthermore, it seems to be generally assumed that the height chosen in any such case is the proper height to give the best results, although there is usually no information available to prove that just as good results would not have been obtained with a height of 3½ feet, for instance, instead of 5 feet. In attributing a gain in economy to higher settings there are other factors also which may be ignored, such as a change in the fuel used, an improvement in the proportions or design of the new boiler as compared with the older ones, better firing methods, improved draft conditions and method of draft control, a better type of grates, etc.

For any set of fixed conditions as regards size of boiler, character of fuel and other details, it is evident that there must be some limit in height of furnace beyond which there will be no gain in economy. It would probably not be possible to fix such a limit very definitely, but much interesting information could be obtained from a series of carefully conducted tests carried out by some agency such as the Bureau of Mines, which would have the necessary apparatus and technical skill, together with the means for insuring that all other conditions remain constant while the height of the furnace is varied.

The combustion volume, and therefore the height from grates to boiler shell, should be varied in accordance with the character of the fuel used, more volume being required for fuels containing a large proportion of volatile matter than for those which contain a relatively greater percentage of fixed carbon. On our setting plans we do not show any fixed dimension for the furnace height, but we recommend certain dimensions as determined from our experience and best judgment. For a 72-inch boiler with tubes 18 feet long, for instance, the heights which we advise would be as follows:

For anthracite coal and semi-bituminous coals containing less than 18 per cent of volatile matter (Pocahontas, Georges Creek, etc.)—36 inches.

For bituminous coals containing from 18 per cent to 35 per cent of volatile matter (Pittsburgh)—40 inches.

For bituminous coals containing more than 35 per cent of volatile matter (Illinois, etc.)—44 inches.

For other sizes of boilers the figures are varied so as to maintain approximately the same ratio of combustion volume to grate area. In this connection it might be mentioned that the ratio of combustion volume to grate area would be nearly 19 to 1 for a 72-inch boiler with 18-foot tubes, set as shown in Figure C and with a height of 44 inches from grates to boiler shell. Although the setting is designed only for hand-fired horizontal tubular boilers, this ratio is considerably in excess of that ordinarly used for stoker-fired water tube boilers, which may be forced to 100 per cent or more above their nominal rating. It would therefore seem that these combustion volumes ought to be more than ample and that no gain in economy should be expected from an increase in the ratio.

Method of Support.

When boilers are suspended in battery it is best to place the supporting columns entirely outside of the setting walls, using only four columns with beams of sufficient strength to support the boilers in a single span. With standard I-beams it is possible to support in this manner three boilers of any diameter not exceeding 78 inches or two boilers of larger diameter. If the installation involves more boilers it is best to set them in separate batteries of two or three boilers each, rather than to use columns in the division walls between boilers; if it is absolutely necessary to use such intermediate columns, an air space should be left all around each one with a suitable ventilating duct to admit air at the bottom. We know of several cases where columns have been burned off or otherwise damaged when built solidly into setting walls.

Our setting plans show the proper sizes of I-beams to use for suspending boilers, together with alternate designs for both round and square cast-iron columns, structural steel H-beams and built-up columns made of plates and angles. In general it will be found that these designs are heavier than those usually employed by boiler manufacturers, but we think that these sizes are needed in order for the columns to have a strength equal to that of all other parts of the installation where it is customary to use a factor of safety of 5. Boiler columns are loaded entirely at one side and the stresses are therefore greater than when the loading is symmetrical as assumed in the tables published in structural steel handbooks. Furthermore, proper consideration should always be given to the "ratio of slenderness," a heavier section being needed for a long column than for a shorter one carrying the same load. I-beams are frequently used for columns, but they are not well adapted for the purpose as the distribution of metal in the I-beam section does not make a good column design. Our Engineering Department can furnish designs for reinforced concrete columns if desired.

Boilers having a diameter of 78 inches or less can be supported by brackets which rest upon bearing plates built into the setting walls, but the suspension method is better, particularly for the larger sizes. Four brackets (two on each side) are sufficient for boiler diameters of 54 inches or less, but eight brackets should be used for boilers larger than this size; the brackets should be located in pairs with a single bearing plate for each pair. Brackets at the front end should rest directly upon the plates, but rollers should be used under the brackets at the rear end to permit free expansion of the boiler. As a rule, not enough care is used in setting the bearing plates, with the result that a good bearing is not obtained over the entire surface of both brackets. In an extreme case the bearing may be only along one edge of one bracket. The boiler should be supported by blocking or other suitable means while the setting is being built and its weight should not be allowed to come upon the walls until the mortar has thoroughly hardened so that there will be no settling.

Installation of Boiler Piping, Valves, Fittings, etc.

Figure C shows a typical longitudinal section through a suspended boiler with overhanging front. Several self-explanatory notes will be found on this

drawing relative to the proper installation of piping, valves and other details. In addition to the items mentioned the following details should receive attention in any well planned installation.

The steam gage should be graduated at least 50 per cent in excess of the maximum allowable working pressure and it should be piped up with a siphon, union cock, drip cock, and connection with stop valve for test gage, brass pipe and fittings being used throughout.

A water glass and three gage cocks should be used. The lowest visible part of the water glass should be at least two inches above the center of the fusible plug and the gage cocks should be located within the range of the visible length of the glass. Brass pipe and fittings, 1¼ inch size, should be used for the water connection to the water column except for small boilers where the minimum size may be 1 inch. To facilitate cleaning, plugged crosses should be used in these water connections in lieu of tees or elbows.

A blow-down pipe should be provided for the water column with a gate-valve or cock. This pipe should have a diameter of at least ¾ inch and should be connected to the ash pit or some other safe and convenient point of waste. It should be secured to the boiler front near the bottom by a pipe-clip or other suitable means.

All valves and fittings should be of extra heavy pattern if the pressure exceeds 125 pounds per square inch. In Massachusetts a State law fixes this limit at 100 pounds.

A sampling pipe for flue gas analysis and three ¼ inch pipes for draft gage connections should be placed in position when the setting is being built, even though it is not expected to use them. The expense is insignificant and they may prove useful.

The foregoing description is intended to cover the more important features connected with the construction of brick settings for horizontal tubular boilers and the installation of such boilers in accordance with good practice, but without any unnecessary frills. As stated before, many of our new setting plans are now completed and available for distribution to our friends upon request. Any inquiries regarding special features in connection with this general subject will receive the best attention of our Engineering Department at any time.

Improving the Saccharimeter.*

Foreign and American Instruments Discussed—Some Criticisms and Recommendations.

By C. A. Browne.[1]

A leading expert in the manufacture of chemical apparatus in this country recently made the statement that the high-water mark period for laboratory instruments, when the purchaser could get the highest standard of excellence for the least money, was reached in the years immediately preceding the late war. The user of apparatus, in his present state of desperation, when the lower possibilities of achievement compel him to accept either inferior instruments or none, looks back upon this pre-war period as a sort of golden age. No one has probably felt the effects of this decline in excellence more acutely than the sugar chemist. During the recent saccharimeter famine it was amazing to note the number of antiquated polariscopes that suddenly emerged from their dusty hiding places. Old instruments of the Duboscq, Scheibler and Mitscherlich types were lacquered up and sold at a handsome figure. An accuracy within three-tenths was cheerfully accepted where an error of one-tenth would previously have meant indignant rejection. Several purchasers of these old instruments brought their finds to the writer's laboratory for examination and some very interesting, as well as amusing, facts were brought to light as a result of this inspection. We must pass over all this, however, and confine our discussion to the observations made upon five different types of saccharimeters with which manufacturers in America, England, France, Germany and Bohemia are attempting to relieve the present shortage.

The first pinch of the war in the experience of American sugar chemists was the difficulty in replacing some of the most ordinary polariscope accessories, such as tubes and tube cover glasses. The case of the cover glass, the simplest piece of apparatus which sugar chemists employ, is instructive, as it offers an excellent illustration of the difficulties which suddenly confronted us. The first substitutes offered by dealers in place of the regulation covers were discs of ordinary window glass, which sold for the magnificent sum of 25 cents apiece. They contained numerous flaws, their surfaces were not plane parallel, and their deep green color impaired the intensity of the light in the field. But for a time, fortunately a brief one, these were the only covers available and chemists had to use them or do without. With the manufacture of optical glass in this country, instrument makers were able to take a long step in advance. Cover glasses were so improved that, as regards optical properties and plane parallelism, they were practically perfect, but as regards durability, they were still inferior

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* Sugar, June, 1920.

[1] President Society of American Sugar Chemists and Technologists, known as the Sugar Section of the American Chemical Society. From an address delivered before the fifty-ninth meeting of that organization in St. Louis, April 15, 1920.

to the old pre-war standard. They split and cleaved easily around the edge; they cost twice as much as the old covers and their life was only about one-quarter as long. After some experimenting it was found that, by more careful annealing and by bevelling the sharp edges of the glass slightly, these defects of fracture could be removed, so that we have finally domestic cover glasses equal to those which were imported before the war.

This illustration of the cover glass is typical and it applies to every single feature of the saccharimeter. The perfection of any instrument is a process of slow growth and evolution and manufacturers who enter a new field must acquire and accumulate experience.

Coming now to the saccharimeter itself, let us consider first the question of general construction, of which there are two distinct types: the open construction, or French type, and the closed construction, or German type of instrument. Each of these types has certain distinct advantages as well as certain distinct disadvantages. The open construction has the advantage of accessibility of parts, and the French saccharimeters can usually be very easily dissected, in some cases without the necessity of removing a screw, the various parts slipping or turning into position. Easy accessibility is desirable in tropical countries, where the prisms require frequent attention, owing to the attacks of fungi which, unless quickly removed, will soon ruin the instrument. It is also desirable in remote localities, in order that damaged parts may be easily detached and sent away for repairs without the necessity of shipping the whole instrument. Objections to the open construction are that it does not exclude dust, that contamination of the wedges, etc, with drops of spilled solution is more easy, that it induces frequent tampering, and that it prevents securing the rigidity necessary for preserving the accurate permanent alignment of the optical parts. These objections to the open construction are all valid, but the advocates of the closed construction have gone too far in the opposite direction. I would criticize especially a familiar model of the closed type in which the parts are fastened in with such a multitude of fittings and screws that it is a day's task to dissect the instrument and reassemble the parts. The most common necessary operation of removing the splash glasses requires the use of a screw driver and, as one of our number has expressed it, "of much profanity." On one recent saccharimeter of the closed type the screw for adjusting the scale is enclosed within the protection case which covers the wedges, so that the rim of the case must be unscrewed and removed before the regulating pin can be turned. Such a contrivance may prevent tampering with the scale, a common fault of young chemists, but will defeat its own purpose in the end, for users of the instrument will soon remove the protection case once for all rather than waste thirty precious minutes every few days to make an adjustment which, through a covered hole in the case, could be made in thirty seconds. There is a happy medium between the closed and open construction toward which manufacturers should aim. The recent model of French saccharimeters shows a tendency toward such a compromise, and the saccharimeter of the future will no doubt combine as many as possible of the advantages, with as few as possible of the disadvantages, of each type.

One other important matter of general construction, which manufacturers should keep in mind, is the observance of a certain conformity with general usage in such details as height, width of trough, etc. The departure of some of the newer instruments from common usage will mean trouble and expense for some laboratories in such matters as making new openings in partition walls for illuminating the saccharimeter, or purchasing extra tubes that will fit troughs of a different diameter. It is a great advantage, and in some laboratories a necessity, to be able to use tubes interchangeably, as in the comparison of readings on different instruments, and this cannot be done when the width of trough varies, as it does on some of the newer types of saccharimeters, from less than 30 mm. to over 50 mm.

Leaving general construction we will discuss next a few of the special features of saccharimeter design which require attention, and the most important of these is the polarizer.

The most accurate polarizer for quartz wedge saccharimeters is generally admitted to be the Lippich. The extreme fragility of the half-prism of this type of polarizer is, however, a most serious defect. The sharp edge of the small prism, which forms the dividing line of the field, is very apt to become shattered, often from no apparent cause. I have had three instances of this in my own experience and the testimony of sugar chemists generally is very similar. An establishment in New York, which repairs a great many saccharimeters, gives disruption of the Lippich half-prism as the most common cause of trouble. When this damage occurs, the saccharimeter is either rendered useless or the accuracy of reading is so much diminished that the initial advantage of the Lippich polarizer is lost. The Jellet-Cornu polarizer, while less sensitive than the Lippich in setting the field, has the advantage of much greater durability. The diminished sensitiveness is frequently the result of too heavy a line of division in the field, due either to too thick a film of balsam between the halves of the prism or to imperfect alignment. On some of the newer saccharimeters these difficulties seem to have been largely overcome, with a great increase in the accuracy of reading.

The French saccharimeters still employ the Laurent polarizer with the quartz half-wave plate. This system has the great advantage of simplicity and of permitting adjustment of the half-shadow angle to any desired degree of brightness with only a very small addition in cost to the instrument. On the other hand, the Laurent system being primarily intended for monochromatic light of one wave length, is not so well suited to the white light requirements of a saccharimeter, as the Lippich and Jellet-Cornu polarizers, even when using a bichromate light filter. The latest saccharimeters with the Laurent polarizer have simple devices for balancing the color inequalities of the field by a slight rotation of the analyzer, but the personal equation factor is not thus entirely equalized, so that the field may appear uniform to one person and irregular to another. The personal equation factor, it should be stated, enters more or less into all saccharimetric measurements where white light is used, no matter what the type of polarizer.

The size of the fixed half-shadow angle for a non-adjustable polarizing

system is a point upon which some manufacturers differ. For a charge of 26 grams in 100 cc. the fixed half-shadow angle for the miscellaneous class of products tested in a sugar and food laboratory ought to be about 7 degrees. Yet one manufacturer is putting out a saccharimeter with a half-shadow angle of 5 degrees, which is much too low for the polarization of dark colored products, and he defends this selection on the ground of increased accuracy in matching the field, stating that if solutions are too dark for this angle they should be clarified more completely. This manufacturer makes, however, the false assumption that the error due to increasing the quantity of clarifying agent is less than the error produced by increasing the half-shadow angle. It is not surprising that some of these new 5 degree angle instruments have been returned to the maker as not usable. Such mistakes as these could be avoided if manufacturers would first subject an undeveloped instrument to a thorough practical test before putting it upon the market. This necessary precaution would protect them against the damaging reports which circulate upon the rejection of a new type of instrument.

All of the recent types of saccharimeters have the double field and this seems to be in complete agreement with the opinion of those who have to make continual use of the instrument in commercial work.

The point upon which, perhaps, most uncertainty was felt about the new saccharimeters was the optical purity of the quartz in the wedges. It had been asserted that the supply of quartz sufficiently pure for cutting good wedges was about exhausted. The length of an ordinary wedge is about 30 mm., and, as far back as twenty years, Landolt[1] made the statement that to possess an optically pure quartz wedge of this length must be considered a piece of rare good luck. The situation would not seem, however, to be quite as bad as represented, and a careful examination of some of the new saccharimeters with a control tube shows that the inaccuracies of scale due to optical imperfections in the quartz wedge are less than 0.05 degree.

It is to be regretted that some manufacturers in the construction of the saccharimeter scale have not had a sufficient regard for the comfort of the observer's eye. One of the new scales examined consisted of very fine lines, ruled upon metal that was scratched and unpolished, and hence very difficult to read. The best of the new scales is a modification of the ground glass scale illuminated by softened transmitted light. A unique feature of this scale is the slight overlapping of the lines of the vernier upon the lines of the scale, which permits the easy estimation of slight differences. A vernier line is easily seen to be continuous with a scale line, or separated from it by a full, half, or quarter break, so that the observer can read to 0.025 degree without difficulty.

The greatest length of any scale is afforded by a French saccharimeter, in which the two equal sized wedges of the quartz compensation are driven past

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1 Das optische Drehungsvermögen, 2nd Edit., p. 339 (1898).

each other in opposite directions by the action of a double rack and pinion, the scale being upon one wedge and the magnifying glass and vernier upon the other. This permits making a scale of double the ordinary length. Such a construction is, of course, limited to instruments of the open type.

Manufacturers of the newer saccharimeters show somewhat different ideas about trough construction. Reference has already been made to the inconvenience resulting from variations in the diameter of trough. The separation of the trough by a small space from the rest of the instrument is an excellent feature of one saccharimeter, as it protects the analyzer and polarizer against the transmission of heat, when polarizing hot solutions, and also by offering a means of drainage prevents accidental flooding of the optical parts when solutions are spilled through breakage or leakage of tubes or otherwise. Some of the new saccharimeters have a trough with a wedge-shaped cross section instead of the familiar semi-circular form. A wedge shape presents no disadvantage with ordinary tubes, but with tubes having projecting attachments, such as the control tube, the inversion tube and continuous tube, the equilibrium in a wedge form is very unstable; the sudden tilting, for example, of an inversion tube, in which a thermometer is placed, may lead to an accident. For this reason the old semi-circular form of trough, which conforms more closely to the outlines of the tube, is generally to be preferred.

Two of the new saccharimeters examined had methods for attaching the illuminating device directly to the instrument. This system has an advantage in that the alignment of the instrument with the lamp is not disturbed by moving, but it has the disadvantage, unless suitable precautions are taken, of communicating heat to the polarizer. One new instrument had a small attachable electric lamp, the current to which from a battery of dry cells could be turned off after each reading by a switch on the front of the instrument. But where readings have to be made for hours at a time with one tube following another, the lamp must burn continuously and, in such cases, the polarizer becomes overheated. It is for this, as well as for other reasons, that the small attachable electric light system of illumination has not generally been favored by chemists. On another new type of saccharimeter the lamp was supported by a long bracket fastened to the base of the saccharimeter and this device was found to protect the polarizer perfectly against heat transmission even after several hours' burning of the light.

All of the newer saccharimeters which were examined offered a means of substituting a section of bichromate crystal or of bichromate colored glass in place of the troublesome cell of bichromate solution. This feature will be found a decided convenience in many commercial laboratories, although for purposes of standardization, or of highly accurate measurement, the regulation cell of bichromate solution should always be the standard of reference.

As to the question of scale standard: One of the more recent types of saccharimeters used a normal weight of 20 grams and two a normal

weight of 26 grams. Manufacturers express themselves as most anxious to please their customers in the matter of scale standards, but are hampered by the lack of sufficient knowledge in regard to the rotation value for the 100 degree point of each scale. We have two opposing official standards for the 26 gram German scale, and there are similar disputes about the French scale. These differences are no doubt due in considerable part to the influence of personal equation, first on the part of the technician who fixes the 100 degree point of the scale, and, second, on the part of the observer who reads the sugar solution, there being slight differences of scale adjustment or of reading on account of the varying sensitiveness of individual eyes to the slight color disturbances in the field of all white light saccharimeters.

The fixing of the rotation value for each particular scale should be settled in the same way; atomic weights, for instance, are fixed by international agreement. No less than twenty-nine determinations by different experimenters enter into the average made by Clarke for the atomic weight of silver. Let measurements of the rotation constant of the saccharimeter scale be made in as many different physical laboratories as possible under the best controllable conditions, and let the International Commission for Uniform Methods of Sugar Analysis prescribe an average value which shall govern the standardization of all saccharimeters. The value thus obtained may not be perfectly true for many individual eyes, but it will be truer for the average eye than the results of a single set of experiments.

The outlook for the manufacture of accurate saccharimeters in countries outside of Central Europe is believed to be most encouraging. The defects which have been noted are mostly in minor matters of construction and can easily be corrected. Manufacturers must necessarily be given time to acquire and accumulate experience. The users and manufacturers of scientific apparatus should work together in a critical yet friendly spirit of cooperation. It was by the intensest kind of such cooperation that the manufacturers of Central Europe attained their high position and manufacturers in other countries must follow a similar course if they are to achieve the greatest success.

[R. S. N.]